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331

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COMPARATIVE EVALUATION OF AIRCRAFT SEATING ACCOMMODATION

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BIO-MECHANICS LABORATORY
SOCIOLOGY DEPARTMENT
TUFTS UNIVERSITY

APRIL 1957

WRIGHT AIR DEVELOPMENT CENTER

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WADC TECHNICAL REPORT 57-136
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COMPARATIVE EVALUATION OF AIRCRAFT SEATING ACCOMMODATION

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SOCIOLOGY DEPARTMENT
TUFTS UNIVERSITY

APRIL 1957

AERO-MEDICAL LABORATORY
CONTRACT No. AF 33(616)-3068
PROJECT No. 7215
TASK No. 71724

WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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FOREWORD

The testing program described in this report was carried out by the inter-disciplinary staff of the Bio-Mechanics Laboratory, Tufts University, Medford 55, Massachusetts, as one effort of a multi-approach comfort evaluation program (Task No. 71724) being conducted as part of the work under Contract AF 33(616)-3068, Project No. 7215, "Human Factors in Design Research."

Mr. Charles A. Dempsey, Biophysics Branch, Aero Medical Laboratory, was the Project Engineer, and Mr. W. K. Carter was the contractor's Project Director. Credit for over-all planning and general orientation of the program should go to Mr. Dempsey and several other staff members of the Aero Medical Laboratory. The authors of this report are indebted to many of the personnel of the Aero Medical Laboratory for briefings on the special problems of aircraft seating. Contributions to the present work by the many researchers of the Biophysics Branch who carried out earlier related studies are gratefully acknowledged.

Procedures for the specific testing program reported herein were planned, and the data analyzed, by Dr. R. F. Slechta. Dr. Edward A. Wade cooperated in the planning of questionnaires and statistical techniques. Mr. Jess Forrest was responsible for work concerned with seat design. Writing the report was a group effort by the authors. Represented in the inter-disciplinary research team were: physiology, psychology, anthropology and industrial design.

The authors wish to thank Mr. Charles LaMuniere and Mr. H. Wade Seaford for technical assistance. We also are grateful for critical appraisals and advice on procedures from Dr. Albert D. Ullman and Dean Leonard C. Mead. We owe particular acknowledgment to Dr. Edward M. Bennett who repeatedly helped with advice on statistics and experimental design, and who aided in organizing the report.

In addition, we feel indebted to the subjects. Their cooperation and earnest attitudes were of primary importance to the project. Many of the subjects were members of the Tufts University AFROTC. Col. Herman Hauck, USAF, Commanding Officer of the unit, and members of his staff, aided in interesting subjects in participating and were helpful to the program on many other occasions.

We should also like to thank Frances E. Leighton, LeRoy Christie, and Thelma B. Carter for aid in preparing the report.

ABSTRACT

Three inter-related purposes were accomplished: (1) A series of seats currently in use in operational aircraft were comparatively tested for adequacy in limiting pilot and crew fatigue and discomfort. (2) Several subjective methods of comfort testing were devised and evaluated to determine efficient and economical means of seat evaluation. (3) The test data were analyzed for basic information about the nature and progression of seating discomfort.

The approach was experimental, using techniques and orientations of an inter-disciplinary research team. Eighteen subjects, selected to represent a wide range of the body sizes in the Air Force population, were seated in each of six seats for tests up to 7 hours in duration. Six by six Latin Squares were utilized for purposes of counterbalancing. Summaries of data and discussions of statistical techniques are presented in appendices.

Results are summarized in an introductory overview and in the conclusions section. Results of several comfort testing techniques were found consistent one with the others. Statistical separation of the seats was demonstrated in analyses of data from voluntary sitting time and other techniques. Statistical treatment of sitting time data from twelve subjects gave essentially the same results as those obtained with 18 subjects. Localized discomfort in the back and buttocks was found more important than discomfort in the thighs, neck, shoulders and lower legs in producing general discomfort. Seat parts were analyzed for their relative importances in achieving comfortable seating.

PUBLICATION REVIEW

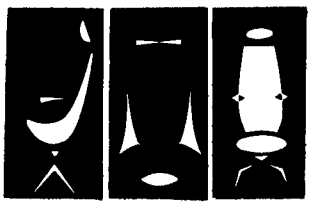
This report has been reviewed and is approved.

FOR THE COMMANDER:

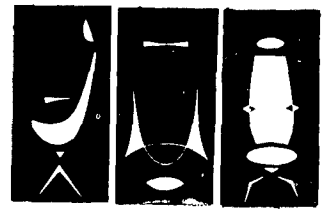
Jack Bollerud

JACK BOLLERUD
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Laboratories

TABLE OF CONTENTS

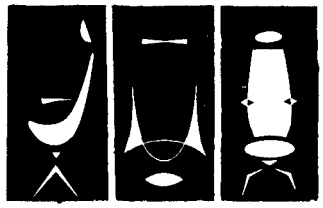


LIST OF FIGURES



LIST OF TABLES

PLAN OF THE REPORT



This report is presented in three parts.

Part I introduces the general problem and summarizes the principal results. It represents an over-view which briefly describes the problem, the purposes of the study, the procedures used, and the general principles derived from the results.

Part II presents a more detailed explanation of the study, together with specific results and their interpretations. It is intended that this part of the report might serve as a guide for any interested investigator who may wish to duplicate parts of the study or to examine the testing procedures and results more closely.

Part III consists of a series of appendices which present a considerable portion of the raw data obtained from the study. This section makes the report a self-contained body of information with summaries of data in the appendices supporting conclusions in the body of the report (Part II), and in the over-view (Part I). Data in Part III may also assist in formulating hypotheses for investigation in future comfort-testing programs. Included in Part III is a presentation of the statistical techniques that were used in the analyses of quantitative data, together with a discussion of the philosophy that governed treatment of subjective information by means of rating procedures and non-parametric statistics. In addition, this section is included to show the great quantity of data obtainable from an intensive and multifarious experimental technique that capitalizes on the specific contributions of a limited number of subjects.

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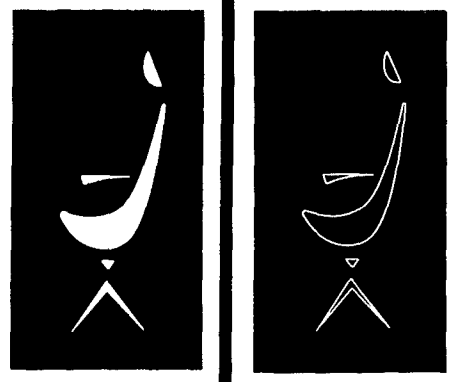

PART 1 OVERVIEW

PART I

THE PROBLEM

Inadequate seating accommodation is one of the many factors which can contribute to the development of pilot and crew fatigue during flights of long duration. Therefore, any research program which is concerned with the optimization of conditions for the maintenance of pilot and crew efficiency must necessarily include studies of seating comfort.

During World War II, when pilot fatigue became a problem of utmost importance, great impetus was lent to the study of aircraft seating accommodation. Intensive research resulted in the establishment of seat design criteria in the form of minimum dimensions required to accommodate nearly the full range of body sizes represented by all flying personnel.

These studies were unquestionably an important contribution, but adequate dimensions in no way assure that a seat will be comfortable. Rather, many other factors are involved. They relate to the manner in which the seat has been designed about basic dimensions; the details of its construction and cushioning; and the addition of features intended to add to comfort. At the present time such factors as these can best be analyzed on the basis of more subjective information solicited from individuals evaluating a seat under controlled laboratory conditions.

The present study exploits this approach to the problem of seat comfort utilizing the advantages of multi-discipline team research. Under static conditions in the laboratory, the study deals with the comfort of seating per se and not with superimposed conditions (e.g. g forces, noise, vibration, etc.) which in themselves produce discomfort in the operational situation.

PURPOSES OF THE STUDY

This report evaluates comparatively the comfort characteristics of a selected series of pilot and crew seats currently in use in operational transport aircraft. By application of the comparative approach with seats possessing various design features, and subjects who have had relatively little past experience with aircraft seats (and thus lack preconceived convictions), it is possible to assess desirable and undesirable features of current aircraft seat design.

A second purpose of the program is to evaluate a series of subjective testing methods in order to determine the most efficient and economical means of seat evaluation.

Finally, it is intended that such procedures may yield useful basic information about the nature and progression of seating discomfort.

SUBJECTS, APPARATUS, AND PROCEDURE

Eighteen subjects were used in the testing program. They were selected on the basis of size from the Tufts University student body and from Bio-Mechanics Laboratory personnel.

Five of the seats tested in the study were selected as being representative of pilot and crew seating accommodations currently provided in operational transport aircraft. A sixth seat, termed "control" seat, was made of plywood and served as a basic or minimum seating configuration.

The subjects were required to sit in the seats for periods up to seven hours. During this time a series of behavioral and questionnaire methods were used and tested as evaluation procedures. Behavioral indices were used as measures of preferences for seats in terms of comfort. Questionnaires administered hourly were designed to gain such subjective information as: how the opinion of the comfort of a seat changes with time; how discomfort progresses in specific body regions; and how experience affects the evaluation of specific design features. A final questionnaire was designed to obtain information based upon the subject's total experience in the seat.

CONCLUSIONS

From the results of this study it was possible to derive certain tentative testing methods from which future investigators might select any of several for seat evaluation.

In addition, the conclusions listed below can serve as guides for the more technically oriented who desire information on the human engineering of seats to improve their comfort characteristics.

1. Sitting Time:

   (1.1) The use of average voluntary sitting time as a measure of seat preference was successful, and statistical separation of the seats was demonstrated. However, because of the great amount of time involved, voluntary sitting time is not recommended for use as a routine procedure.

   (1.2) Since most of the subjects voluntarily left the seats after four to five hours, it is suggested that this length of time is adequate for most seat testing purposes.

   (1.3) Statistical treatment of sitting time data obtained from twelve subjects gave essentially the same results as those obtained with eighteen subjects. This suggests that, in a properly designed experiment, the smaller number of subjects is adequate.

2. Rating Scales:

(2.1) The use of rating scales to determine seat preference was a short and efficient means of assigning relative "scores" to seats.

3. Hourly Evaluation of Comfort:

(3.1) The hourly evaluation of the degree of comfort provided by a seat was a useful procedure both for ranking the seats and for following progressive changes of opinion concerning the comfort of the seats.

(3.2) Hourly predictions by a subject of how much longer he could sit in a particular seat were useful for ranking the seats. The method also was able to single out seats which at first seemed more comfortable than they actually became later.

4. Body Regions in Seating Discomfort:

(4.1) Average hourly discomfort scores obtained for each body region revealed that the body regions, in order of decreasing importance in seating discomfort were: the buttocks, the back, the thighs, the neck, the shoulders, and the lower legs.

(4.2) Discomfort in the buttocks and back most directly influenced the ranking of the seats.

(4.3) Discomfort in the thighs was of little importance in all except one of the seats, and could not be used in ranking the seats.

(4.4) Discomfort in the neck was negligible and had little influence on the ranking of seats.

(4.5) Discomfort in the shoulders and in the lower legs was negligible and had little influence on the ranking of the seats.

5. "Total Discomfort" Scores:

(5.1) Total discomfort scores (gross indices of discomfort derived by summing average hourly discomfort scores obtained for specific portions of the body) were useful in ranking the seats, and could be used profitably in tests of the order of four to five hours in duration.

6. Onset of Discomfort:

(6.1) The average time of onset of discomfort was a useful means for ranking the seats. Since the time of onset is closely related to the total amount of discomfort experienced in the seat, onset may be used as an indirect index, or predictor, of total discomfort.

7. Body Discomfort and Seat Design:

(7.1) Inadequate cushioning was largely responsible for buttocks discomfort and was shown to be nearly as detrimental to comfort as complete lack of cushioning.

(7.2) Lack of adjustability in the seat back was a partial cause of back discomfort.

(7.3) Discomfort in the thighs was of little importance except in one seat where a bar-type thigh pad caused excessive discomfort.

(7.4) Short seat cushions also contributed to thigh discomfort.

(7.5) Discomfort in the lower legs was negligible, but was influenced by the same factors which caused thigh discomfort.

(7.6) Presence or absence of a headrest had little effect upon neck comfort, but seat back adjustability and armrests tended to alleviate neck discomfort.

(7.7) Shoulder discomfort had negligible influence on the ranking of seats, but shoulder comfort was adversely affected by lack of seat back adjustability.

8. Summaries of Seat Evaluations:

The following are summaries of data obtained for each seat. Suggestions listed below are taken directly from appraisals made by the subjects.* Seats are listed in decreasing order according to subject preference.

C-118 Pilot Seat (Aerotherm)

Average length of voluntary sitting time		400.4 min.
Average time of onset of discomfort		220.0 min.
Total discomfort score		3.9
Comfort scale rating**		+ 6.59
Most used vertical adjustments (SRP to floor)		15", also 16" to 16½"
Most used seat angle adjustments (with respect to horizontal)	(Seat pan fixed at 9°)	Back 100° & " 106°

Suggestions:

Headrest should be added

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*Suggestions include only those made by five or more subjects.
**A relative measure of discomfort-comfort, range -10 to +10.

C-124A Pilot Seat (Gravity Load) (Weber)

Average length of voluntary sitting time	368.3 min.
Average time of onset of discomfort	189.2 min.
Total discomfort score	7.1
Comfort scale rating	+ 5.24
Most used vertical adjustments (SRP to floor)	15", also 16½" to 18"
Most used seat angle adjustments (with respect to horizontal)	Seat pan 1° - Back 104°& " " 3° - Back 109°

Suggestions:

Seat cushion is too firm.
Seat back is too firm.
Seat back offers poor support for small of back.
Headrest is too high (29").
Armrests are too short (15") and narrow (3").
Lateral adjustment is difficult to make.

C-97A and KC-97E Pilot Seat (Long Range) (Weber)

Average length of voluntary sitting time	365.9 min.
Average time of onset of discomfort	198.0 min.
Total discomfort score	6.7
Comfort scale rating	+ 3.27
Most used vertical adjustments (SRP to floor)	14½" to 16", also 17½"
Most used seat angle adjustments (with respect to horizontal)	Seat pan 1° - Back 104°& " " 3° - Back 109°

Suggestions:

Seat cushion is too soft.
Seat cushion is too short without thigh pads (14").
Seat back offers poor support for small of back.
Headrest is too high (29½").
Armrests are too short (14½"); too narrow (3½"); too high, (9" from seat), and too close together (18½").

C-124 Crew Seat (Weber)

Average length of voluntary sitting time	308.2 min.
Average time of onset of discomfort	134.5 min.
Total discomfort score	15.7
Comfort scale rating	- 0.97
Most used vertical adjustments (SRP to floor)	18", also 20" to 20½"

Suggestions:

Seat cushion is too soft and too short (13-3/4").
Seat back is too soft and gives poor support to shoulders, middle of back, and small of back.
Headrest is too high (27").
Armrests should be added.
Adjustable back is needed.
Height adjustment is difficult to make.
Fore and aft adjustment hard to reach, and difficult to move.
Swivel adjustment is difficult to make.

C-124A Crew Seat (Hardman Model 605)

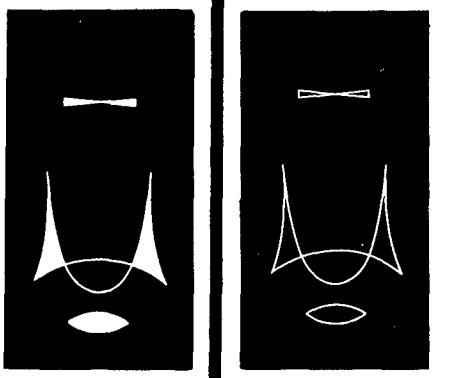
Average length of voluntary sitting time	309.9 min.
Average time of onset of discomfort	112.6 min.
Total discomfort score	18.4
Comfort scale rating	- 1.11
Most used vertical adjustment (SRP to floor)	17¼"

Suggestions:

Seat cushion is too short without thigh pads (16"); too narrow (16"); and too soft.
Seat back is too narrow (tapering) and offers poor support to shoulders, middle of back, and small of back.
Thigh pad is uncomfortable.
Headrest should be added.
Armrests should be added.
More range in vertical adjustment is needed.
Back adjustment is needed.
Vertical adjustment is inaccessible or hard to reach and hard to move.
Fore and aft adjustment is difficult to make.

Control Seat (Plywood)

Average length of voluntary sitting time	267.1 min.
Average time of onset of discomfort	99.1 min.
Total discomfort score	18.3
Comfort scale rating	- 5.29



PART 2
THE EXPERIMENT

PART II

INTRODUCTION

With the advent of advanced propulsion systems and the resulting long range and high altitude flight profiles, the problem of efficiency and endurance of pilots and crew becomes even more critical. Success of the mission depends not only upon systems performance but on human effectiveness.

Among the many variables shown to affect human efficiency are those of fatigue and stress imposed upon man by the increased performance capabilities of his aircraft. The factors which contribute to pilot and crew fatigue are many and varied. Important are noise and vibrations; extremes of cockpit temperature and humidity; the constant demand for alertness, and even the physical manipulation of controls. Many such factors have been studied in recent research programs. One factor which has been given relatively little systematic study is the discomfort which develops as a result of inadequate seating accommodation.

Traditionally, pilot and crew seat design has primarily been dictated by engineering feasibility rather than by the comfort of the seated occupant. While engineering feasibility necessarily imposes a limit on aircraft seat comfortization, a logical approach to seat design should begin with human comfort in mind.

In the past, several studies on aircraft seating have been based on this premise. During World War II, when the problem of pilot and crew fatigue became paramount, some significant basic work on aircraft seating was accomplished. Perhaps the most important of these studies were those involving the determination of adequate seat dimensions by anthropometric methods. The railroad seat study by Hooton in 1945 (7) lent impetus to this approach to the seating problem. Randall and his co-workers at the Aero-Medical Laboratory subsequently applied these methods to aircraft seating. Studies by this group (12, 13, 15) aided in the establishment of minimum standards for aircraft seat dimensions which were adequate for nearly the entire range of body sizes of flying personnel. These standards were incorporated into seat specifications set forth in the Handbook of Instructions for Aircraft Designers (HIAD) (18).

Without question, these studies were a great contribution to the improvement of seating comfort. However, while the dimensions of a seat might be consistent with the ranges of body dimensions of the seat occupants, this in no way assures that the seat will be comfortable. Rather, there are many other factors involved which can presently be analyzed only on the basis of more subjective information.

Perhaps the most important reason that evaluations of seat comfort have lagged behind investigations of other more dynamic factors is that such studies do not lend themselves well to usual experimental procedures. Complicating the

experimental approach to seat evaluation are conditions such as the presence of too many uncontrollable variables inherent in individual seat design; the difficulty of dealing with subjective methods and data; and - perhaps of most importance - lack of basic information about the psychological and physiological implications of human comfort-discomfort and the role it plays in the development of fatigue.

Despite these difficulties, the need for more adequate and tested methods of seat evaluation is obvious. The importance of seat comfort in the maintenance of operational efficiency and in delaying the onset of fatigue has long been recognized. Indeed, in some instances, crashes of fighter aircraft have been attributed to pilot fatigue caused by uncomfortable seating (16).

Studies of the dynamic aspects of seat comfort are desirable. These can be accomplished only in operational situations. But first seating configurations should be tested in the laboratory under static conditions. In this manner the initial tests derive information uncomplicated by factors such as vibration and cramped workspace. Thus, the laboratory study of static seat comfort deals with the comfort of the seat per se, and not with superimposed conditions which, in themselves, produce discomfort.

The primary purpose of the studies described in this report is to use a multi-discipline research team approach to the comparative laboratory evaluation of the comfort characteristics of a series of pilot and crew seats currently in use in operational transport aircraft. By application of comparative methods with seats possessing varying design features and subjects who have had relatively little past experience with aircraft seats (and thus lack preconceived convictions), it is possible to assess desirable and undesirable features of current aircraft seat design.

A second purpose of the program is to evaluate a series of subjective methods in order to determine the most efficient and economical means of seat evaluation.

Finally, it is intended that such procedures may yield useful basic information about the nature and progression of seating discomfort.

EQUIPMENT, SUBJECTS, AND PROCEDURE

SEATS

Five of the seats tested in the study were selected as being representative of pilot and crew seating accommodations currently provided in operational transport aircraft*. The sixth seat, which served as a basic or minimum seating

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*While many other seats could have been selected, those used in this study are sufficiently differentiated in style and construction to satisfy the purposes of comparative evaluations of both seats and testing methods. If these purposes have been accomplished by this experiment, the methodological approach to comfort testing will have been proved. Should future needs require comfort evaluation of other seats, the investigator will have a number of testing procedures from which to select those which best suit his purposes.

configuration was made of plywood. For purposes of identification, it was termed the "control" seat.

Upon receipt of the seats at the laboratory, they were mounted on 3' x 7' platforms and assigned numbers for easy reference. The following is a list of the numbers assigned to the seats, together with seat nomenclature:

1. C-97A; KC-97E, Pilot Seat (Long Range) (Weber). Figure 17, page 65.
2. C-124A Pilot Seat (Gravity Load) (Weber). Figure 18, page 67.
X. Control Seat (Plywood). Figure 19, page 69.
4. C-124A Crew Seat (Hardman Model 605). Figure 20, page 71.
5. C-124 Crew Seat (Weber). Figure 21, page 73.
6. C-118 Pilot Seat, (Aerotherm). Figure 22, page 75.

Seats #1, #2, and #6 are pilot seats, all having armrests and adjustability in seat pan and back angles. These seats are also adjustable in height, and fore and aft directions. Seats #1 and #2 have headrests and thigh pads, while Seat #6 possesses neither of these features. Other variations in the three pilot seats are in the types of cushioning and upholstery, the ranges of adjustments, the location of adjustment controls, and over-all dimensions. Platforms of all pilot seats were equipped with adjustable footrests.

Seats #4 and #5 are crew seats having no armrests and having fixed seat pan and back angles. Both seats also have height, fore and aft, and swivel adjustability. Seat #5 possesses a headrest, but no thigh pad; while Seat #4 possesses a thigh pad, but no headrest. Further variations in the seats are in the types of cushioning and upholstery, the location of adjustment controls, and over-all dimensions. No footrests were used with the crew seats.

The control seat (#X) is made of plywood, lacks cushioning, and is not adjustable. The fixed seat pan and back angles are 9° and 109° respectively, with respect to the horizontal, these angles having previously been determined as preferable for the maintenance of reasonable alertness (5).

More detailed information about the seats may be found in the legends accompanying pictures of the seats. (cf. Figures 17 to 22, pages 65 to 75).

SUBJECTS

Subjects in the testing program were chosen from the Tufts University student body and from Bio-Mechanics Laboratory personnel. Twenty subjects were selected on the basis of stature to represent the 2nd (64") through the 99th (75") percentiles of U.S. Air Force flying personnel as reported by Hertzberg, Daniels, and Churchill in their anthropometric survey of 1950 (6). Eighteen subjects completed the series of tests. In weight, they ranged from the 2nd (126 lbs.) to the 97th (206 lbs.) percentiles. Ages were from 18 to 33 years.

During the study rather complete body dimensions were recorded for each of the subjects, using the measures and methods of the 1950 anthropometric survey (6). These measurements were made to permit more complete comparisons with the U.S. Air Force population, and to provide complete size data for anyone interested in comparing these subjects with subjects in other comfort studies. With similar

intent the subjects were photographed in standard somatotyping poses. The complete anthropometric data and the photographs are on file at the monitoring Air Force facility and in the contractor's records. A summary of the subjects' body dimensions, limited to those measurements seeming most pertinent to comfort studies, is presented in Appendix I, pages 79 and 80.

PROCEDURE

In planning the sequence in which each of the six seats was to be tested by each subject, 6 x 6 Latin Squares were set up for purposes of counterbalancing. This procedure was used to eliminate the possibility that the order in which the seats were tested would bias the results. Three identical squares were used with two of the sequences repeated a fourth time for the remaining two subjects. (See Table 12, Appendix III, page 93.) Due to the dropping out of two subjects, however, and some lost scores (see footnote page 16), only two intact squares remained at the completion of the testing program. Tests were scheduled a week apart for each subject and usually began between 9:00 A.M. and noon. On any one day two or three subjects, each in an isolated testing booth, were run simultaneously by one monitor.

At least two days prior to a subject's first seating test, a conference was held with him during which the purpose and general procedures of the testing were explained. The subject was then instructed to get no less than his usual amount of sleep during the two nights prior to the test, and to eat only a normal breakfast before coming to the laboratory. He was further instructed to observe these regulations for all subsequent tests.

The testing program was divided into three phases: (1) pre-test preparation of the subject, (2) the sitting test proper with its periodic assessment of comfort by means of questionnaires presented hourly, and (3) a post-test session in which the subject's over-all impressions of the seat were recorded.

Phase I: Pre-Test

When the subject arrived at the laboratory on the day of the test, he was first fitted with an anti-gravity suit, which he wore uninflated and loosened, and was then asked to fill out a Pre-Test Questionnaire (Appendix II, pages 82 and 83). This questionnaire was designed to give information about the subject's general fitness for the test, the comfort of his clothing and the room temperature.

When the subject reported that he had slept less than six hours during the night before the test, that his muscles were sore, or that he was not feeling well for some other reason which might interfere with the test, the test was rescheduled. If the subject reported that his clothing or the room temperature was uncomfortable, adjustments were immediately made to correct the conditions.

After the subject was determined by the experimenter to be fit, his wrist watch was removed and he was given final instructions before starting the test. He was informed that he would be given a lunch 1½ hours after beginning the test; that, during the test, he would be permitted to study, but not to write; that he would be permitted no conversation except with the test monitor; that, after the first questionnaire was completed, he would be free at all times to make any

adjustment the seat allowed; that he would be permitted any movement in the seat that restrictions by the shoulder harness and lap belt would allow. He was also told that if and when his state of discomfort became such that he felt compelled to leave the seat, he was to inform the test monitor and the test would be terminated, but that if his discomfort did not reach this level, the monitor would terminate the test at his discretion. Actually, the procedure was planned so that, if the subject did not voluntarily leave the seat, the test would be terminated by the monitor after 420 minutes (i.e., 7 hours).

Phase II: Testing Session

After the preliminary instructions had been given, the subject was conducted to a testing booth and asked to sit in the seat. The shoulder harness and lap belt were fastened and adjusted for comfort, but the inertia reel was left unlocked. All seat adjustments had previously been set in neutral positions. The subject was then asked to familiarize himself with the ranges of adjustments and with the controls. He was told to start the test with the seat back in the most upright position, but to adjust the height of the seat and the footrest to the most comfortable positions.

When the subject announced that he had adjusted the seat for maximum comfort, the first presentation of the Test Questionnaire (Appendix II, pages 84 to 88) was given, and the time was recorded as the beginning of the test period.

While the subject was filling out the questionnaire, the monitor recorded on a prepared form (Appendix II, page 89) the initial adjustments read directly from indicators which had been mounted on the seats.

The Test Questionnaire was designed to gain such information as the degree of general comfort the seat provides at the moment; the degree and type of discomfort experienced in specific body regions; and the evaluation of specific parts of the seat such as the cushions, headrest, armrests, etc., in terms of the comfort they provide at the moment. The latter part of the questionnaire deals with the comfort of room temperature, clothing, and other extrinsic factors which may influence seat comfort. If complaints were made in this part of the questionnaire, steps were immediately taken to correct the conditions.

This same Test Questionnaire was repeated every hour during the test period in order to cause the subject to focus periodically on his state of comfort and to follow changes in the progression of discomfort. Each questionnaire was numbered successively beginning with No. 1 which was given at 0 hours.

After Test Questionnaire No. 1 was completed, the subject was told that he was now free to make any adjustment of the seat, including the back angle, at any time. Whenever the subject made an adjustment, the change and the time were recorded. During the course of the experiment, a log was kept in which spontaneous remarks by the subject about the seat were recorded.

When the subject complained that his state of discomfort was such that he felt compelled to leave the seat, the time was recorded as the end of the test and a final presentation of the Test Questionnaire was made immediately. If this state of discomfort was not reached, the test was terminated after 420 minutes (7 hours) by the monitor.

After completion of the final Test Questionnaire, the subject was asked to move the adjustment controls in order to form an opinion as to their accessibility, ease of operation, and adequacy of range of adjustment. When the subject was satisfied that he had arrived at an evaluation of the controls, he was instructed to leave the seat.

Phase III: Post-Test

At this time, the subject was asked to fill out a Post-Test Questionnaire (Appendix II, pages 90 to 92). This questionnaire solicits specific information about how each seat part could be modified to offer more comfort in terms of dimensions, location, fabrication, etc., and about the range of adjustments and manipulation of adjustment controls. A section is also provided in which the subject can write any statements he wishes to make. Finally, the subject is asked to rate the seat in terms of the general comfort it provided. Comfort was rated on a 20-point scale which was made up with a minimum of structuring, having three major points consisting of a neutral point and extremes specified as "ideal comfort" and "intolerable discomfort."

RESULTS

SITTING TIME

It is obvious that the comfort of a seated individual is closely related to the length of time he has been sitting; the longer one sits, the more uncomfortable seems the seat. This observation suggests that sitting time may be potentially useful as an index of seating comfort.

On the assumption that after protracted sitting, an individual, if he is free to do so, will get out of a seat even when there are no apparent extrinsic factors forcing such behavior, the voluntary termination of the sitting experience may be taken as a behavioral expression of tolerance for the seat. When discomfort is specified as a condition of voluntary termination of the sitting period, sitting time becomes a useful tool for evaluating seats.

Sitting time has been used in two different ways in previous studies of seating comfort. In some experiments, time was held constant at, e.g., 2, 4, or 8 hours in order to determine and compare changes in comfort state as a function of time (8, 11, 14). In this manner, it has been possible to evaluate a given seat in terms of the lengths of time it took subjects to reach a given degree of subjective discomfort.

In other studies, sitting time was allowed to vary in order to determine preferred angle configurations in adjustable seats (1, 5, 13). A subject sat in a chosen angle configuration until he expressed a desire to change. Preferences were determined by the relative lengths of time spent in each of the various angle configurations.

For the present study it seemed that relative lengths of sitting time might serve to determine the order of preference for the series of seats to be evaluated. The preferential order so determined could then be compared with

orders of preference determined by other, simultaneously administered, methods of seat evaluation. In this manner, the usefulness of sitting time as an evaluative technique could be ascertained.

The time of presentation of the first Test Questionnaire was recorded as the beginning of sitting time. The subject was instructed to inform the experimenter when his state of discomfort reached such a degree that he felt compelled to leave the seat. At this time the final Test Questionnaire was presented and the time of presentation was recorded as the end of the sitting period. If the subject did not voluntarily end the test after 420 minutes (i.e., 7 hours), it was terminated by the monitor. Thus, sitting time was theoretically a measure of the length of time a seat could be tolerated rather than a measure of how long it remained comfortable.

Statistical interpretation of data is based upon the experimental design and individual sitting times appearing in Tables 12 and 13, Appendix III, pages 93 to 95. For purposes of immediate relevance and clarity in text, only group measures of performance (viz., means and standard deviations) are presented in the discussion to follow. In keeping with this general procedure, only those summary measures relating to statistical inferences (viz., F-ratios and probability levels) are presented in the text of this section.

Table 1 presents the mean sitting times and standard deviations for each seat. These group measures are presented for twelve subjects whose scores could be used for rigorous statistical treatment.*

Table 1

Summary of Sitting Time Data

	Seat #1	Seat #2	Seat #X	Seat #4	Seat #5	Seat #6
Mean (12 subjects)	365.9	368.3	267.1	309.9	308.2	400.4
Standard Deviation	78.5	60.3	57.5	93.3	74.1	30.6
Mean (18 subjects)	365.6	375.5	251.8	296.4	297.5	403.5
Standard Deviation	73.4	55.3	65.8	85.0	78.0	26.9

The measures outlined for the complete sample of 18 subjects are included to suggest that general results are relatively independent of group composition.

---

*It is noted on pages 13 and 93 that a replicated Latin Square design (3) was set up for the experiment. Because of missing scores and the loss of two subjects, only two squares (12 subjects) could be used. Missing scores arose in the following manner: In six instances seating tests were interrupted and terminated by the experimenter for reasons such as emergency telephone calls for the subjects, inclement weather, and sudden illness on the part of the subject. Re-runs were not attempted because of the possibility of contaminating results with the earlier, interrupted experience and because of re-scheduling difficulties.

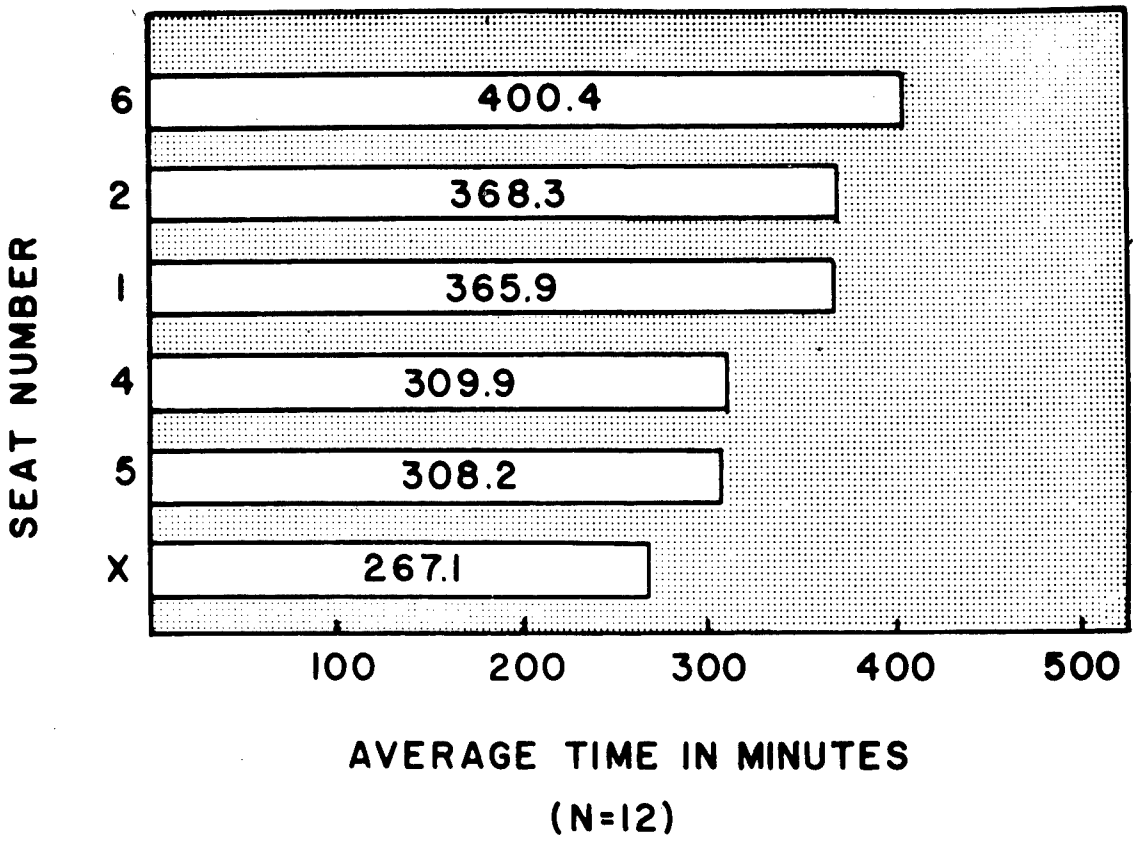

Figure 1

Average Sitting Time as a Function of Seat
(for Subjects from Replicated Latin Square)

The mean sitting times for the different seats are outlined in Figure 1 for the attemuated group of 12 subjects. These measures may be considered as indicating the preferential ordering of seats by the subjects. Such relative preference may be thought of as evidence for relative comfort. Inspection of Figure 1 shows that order of preference is as follows: Seat #6 is most preferred; Seats #2 and #1, which were almost the same, rank next; Seats #4 and #5, virtually indistinguishable, are next in rank; and the control seat, #X, ranks lowest. The differences among seats in terms of mean sitting times were statistically significant ($F = 9.60$, $p < .01$). Mean differences in sitting times for seats were tested further by the Duncan Range Test (2). Analysis indicated that the six seats could be divided into two significantly different sub-groups on the basis of average sitting time ($p < .05$). Differences between seats within sub-groups were not, however, statistically significant. Seats #X, #4, and #5 made up one sub-group of seats characterized by short sitting times, while Seats #1, #2 and #6 constituted a second grouping of seats that could be tolerated for significantly longer periods. These two sub-groups can be seen from inspection of Figure 1. It is thus clearly shown that pilot seats are given preference in

terms of comfort over crew-type seats and that the latter are statistically indistinguishable from the minimum seating configuration represented in Seat #X. It must be remembered that since the cut-off time of the tests was 420 minutes, and since 7 of 12 subjects testing Seat #6 went the full time, it is likely that, had the maximum allowable time been longer than 420 minutes, average sitting time for Seat #6 would have been considerably longer.

Sitting time also varied as a function of session ($F = 2.63$, $p < .05$). During initial sessions, tolerance was high independent of the seat being used. Thereafter, there was a drop, with a rise in tolerance appearing around the third or fourth session. These trends are reflected in Figure 2 which shows sitting time as a function of testing session both for the basic sample of 12 subjects and for the more inclusive sample of 18 subjects (cf. Table 15, Appendix III, page 97).

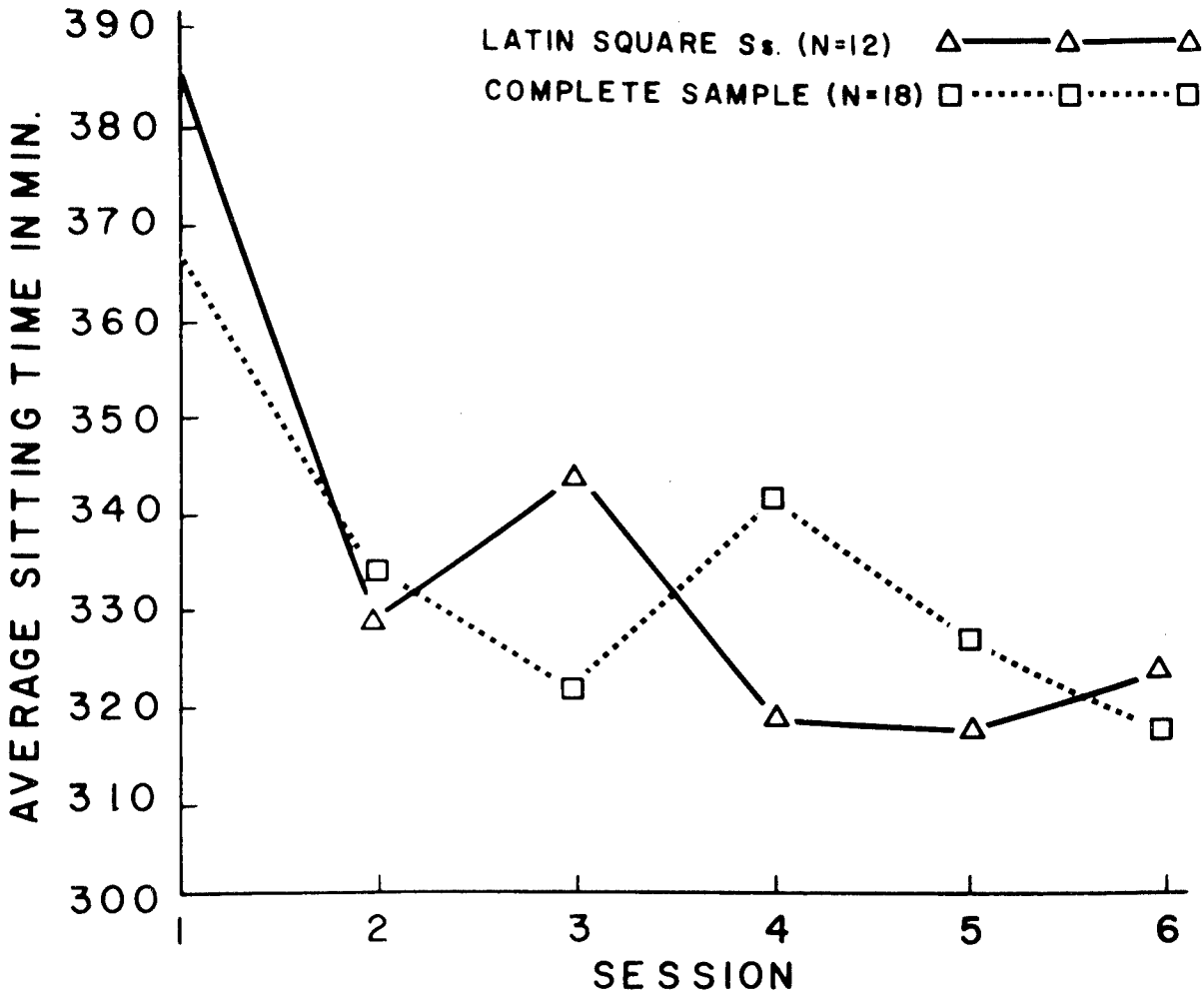

Figure 2

Sitting Time as a Function of Session

It is interesting to note that the six unique serial arrangements of seats for testing purposes did not contribute a significant source of variation. ($F = 1.31$, $p > .05$). This indicates that there was no evidence that the testing of seats in one of these sequences was more advantageous than with any of the remaining sequences.

RATING SCALE

One of the simplest means for determining the degree of general comfort provided by a particular seat is to ask the individual who has used it. In the final analysis, he is the comfort-measuring instrument.

Among past approaches to the evaluation of seating comfort, some have included variations of a rating-scale procedure. Seats have had descriptive adjectives applied to them (e.g., "extremely comfortable," "mildly comfortable," "mildly uncomfortable," etc.). In other situations seats have been rated on some form of scale, categorical or numerical in nature, ranging between the extremes of comfort (10, 19).

In the present study it was decided that a rating scale would be of value, and that this approach would serve best if the subject was allowed to make a decision about the seat on the basis of his total experience with it.

The last question in the Post-Test Questionnaire (which was administered after the sitting period had ended) asked the subject to assign the seat to some position on a comfort continuum ranging from "Intolerable Discomfort" to "Ideal Comfort." (cf. Appendix II, page 92.) The question was as follows:

D. Place a check mark somewhere along the scale below to show how you would rate this seat in terms of the comfort it affords. Record your impressions, taking everything in general into account.

The scale was purposely set up with a minimum of structuring since little or no work has been done on the psychometric problem of scaling comfort by means of adjectives having well-defined scale positions. In order to aid the subject in assigning scale positions, the continuum was arbitrarily provided with ten divisions on either side of neutral.

After a subject had assigned a seat to its position on the continuum, his placement was assigned a "Rating" by numbering the division marks from -10 (Intolerable Discomfort) through 0 (Neutral) to +10 (Ideal Comfort) (See Appendix VIII, page 111 for philosophy underlying the use of rating procedures in this report.).

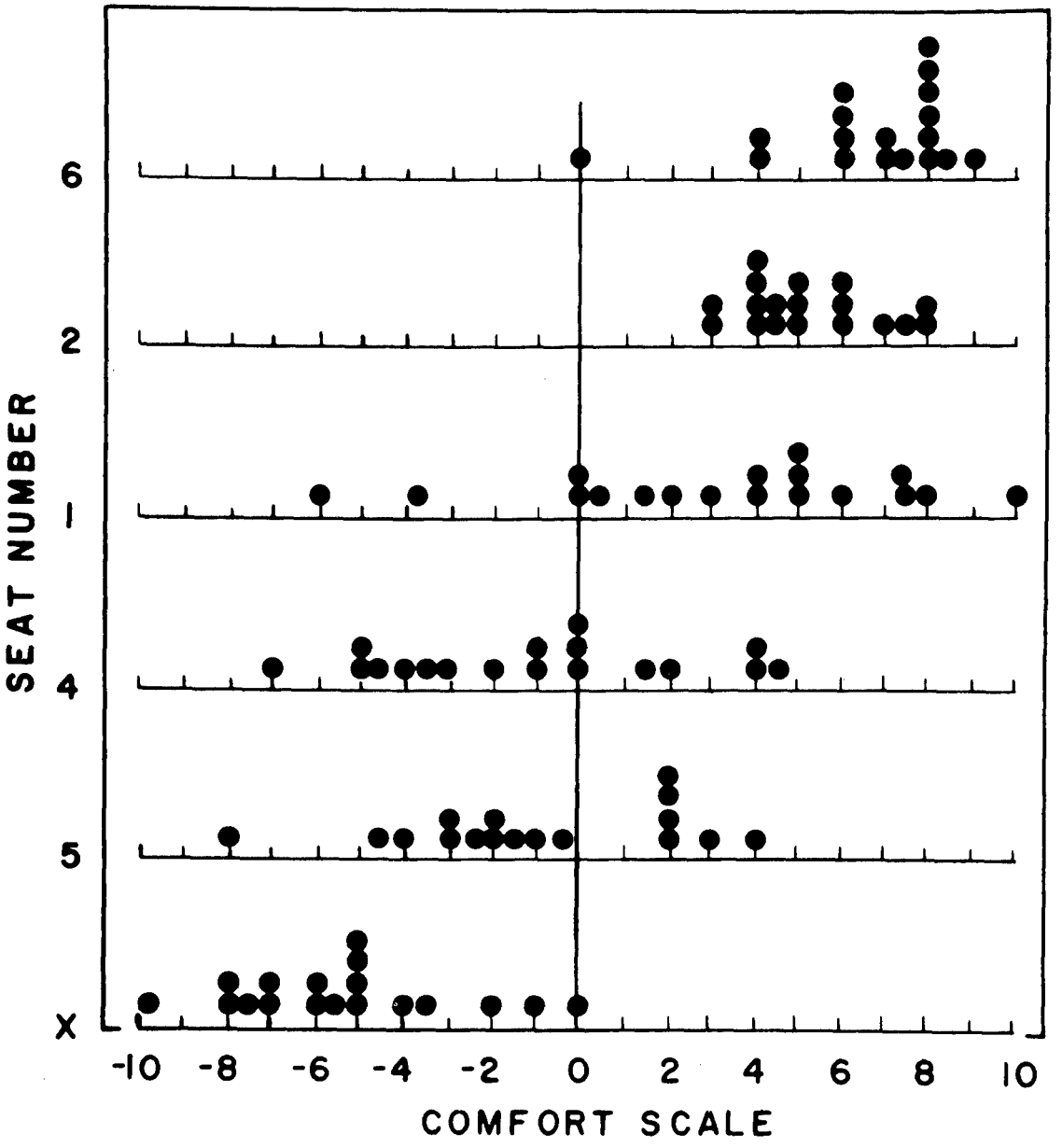

Figure 3

Scattergram of Comfort Scale Ratings

Scattergrams of the individual ratings for each seat are shown in Figure 3 (cf. Table 16, Appendix IV, page 99). The spread of scores and over-all trends in group preferences for the different seats are immediately noted. Certain seats were consistently placed high (plus), or low (minus) on the continuum, while other seats were placed more indeterminately. Seat #6 was one of the seats typically rated high in comfort. Except for three evaluations, all scores for Seat #6 were +6 or higher. Seat #X was at the other extreme. Scores for this seat were in the direction of discomfort and, with the exception of four cases, were of the order -5 or less. Both in ranges and in score frequencies,

Seats #6 and #2 were most consistently evaluated. The remaining seats had greater ranges of scores.

The average ratings for the seats as shown in Table 2 indicate that the seats may be ranked in terms of general comfort in the following order: Seat #6 is rated highest; Seat #2 ranks next; Seat #1 ranks third; Seats #4 and #5 are ranked very closely; and Seat #X is ranked very low. Note that the ordering of seats according to average scale evaluation very closely approximates the order determined by average sitting times. In addition, the distinct sub-groupings of seats (cf. Figures 1 and 3) are much the same for scale evaluation as for sitting time.

Table 2

Average Comfort Scale Ratings

Seat #	Average Rating
6	+ 6.59
2	+ 5.24
1	+ 3.27
5	- 0.97
4	- 1.11
X	- 5.29

To determine whether subjective evaluations had sufficiently differentiated the seats, the six scale ratings - one per seat - were ranked for each subject (Table 16, Appendix IV, page 99). The seat receiving the highest rating was assigned rank 1, the next highest rating received rank 2, etc. A Chi-Square test to determine the significance of ranked data was then applied (4). Analysis revealed that the six seats could be differentiated statistically on the basis of the ranked scale ratings ($\chi^2 = 63.04$ for 5 d.f., $p<.001$).

SUBJECT ATTRITION DURING THE SEATING TESTS

The following sections of this report (pages 23 through 46) deal with data obtained from the Test Questionnaire. This questionnaire (Appendix II, pages 84 to 88) was administered once each hour.

It has been previously mentioned that the first Test Questionnaire was administered at the time that the subject entered the seat (i.e., 0 hours), and that it was numbered as Test Questionnaire No. 1. Subsequent hourly questionnaires were numbered successively. Thus Test Questionnaire No. 2 was given after one hour of sitting; Test Questionnaire No. 3 after 2 hours of sitting; Test Questionnaire No. 4 after 3 hours of sitting, etc. When a subject voluntarily ended the test because of discomfort, a final Test Questionnaire was immediately administered. Therefore the number of the final Test Questionnaire did not necessarily correspond with a whole number of hours.

Figure 4 is a representation of subject attrition for the various seats. It shows the numbers of subjects involved in the data collected from each hourly Test Questionnaire. Differences in the number of individuals starting on a given seat are explained earlier in the report (cf. footnote page 16).

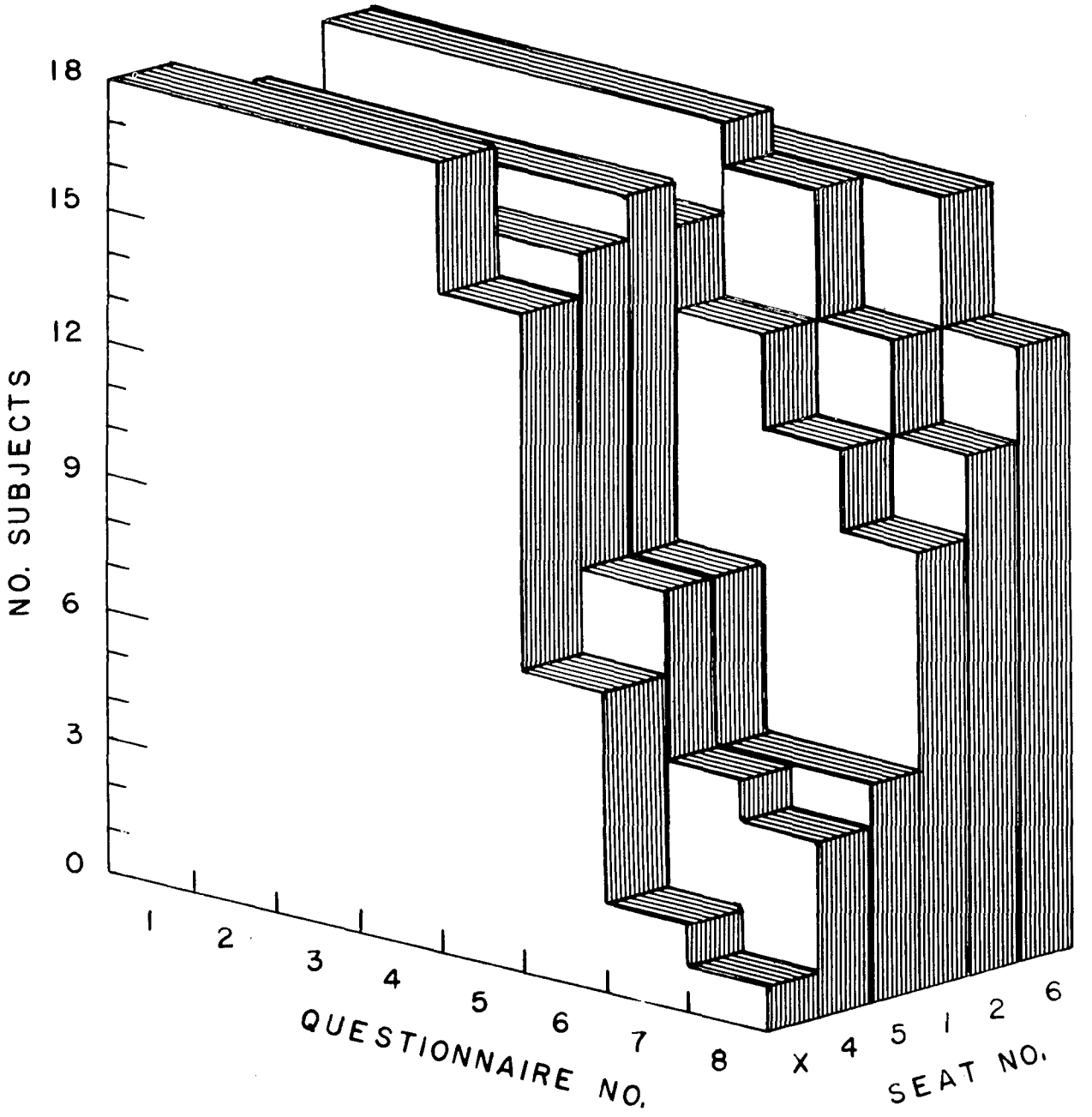

Figure 4

Number of Subjects Involved
in Each Hourly Test Questionnaire

Certain marked consistencies shown in Figure 4 corroborate earlier findings with respect to both sitting time and scale evaluation procedures. As before, Seats #6, #2, and #1 form a sub-group distinct from that made up by Seats #5, #4, and #X. For the former grouping, attrition rate was not too marked, and at least 12 or more subjects were able to complete the entire series of Test Questionnaires

(i.e., to sit for 7 hours) in each of the three seats. For Seats #5, #4, and #X, on the other hand, attrition was greater and the rate quite rapid after Test Questionnaire No. 5 (4th hour). Attrition was greatest for Seat #X as might have been expected from its construction. Here, only 2 subjects remained after Test Questionnaire No. 6, with only one subject able to last the full 7 hours. It is interesting to note that seats ranked closely together by the various tabulation techniques are also similar in rates of subject attrition; i.e., attrition rates are approximately the same for Seats #2 and #1, and also are nearly the same for Seats #5 and #4. It will be recalled from earlier discussion that Seats #2 and #1 are pilot seats having adjustable seat pan and back angles while Seats #5 and #4 are the two crew seats lacking this adjustability.

Figure 4 also reveals that the fifth questionnaire was a critical point at which there was the greatest attrition of subjects. Thus the trends indicated by data taken from questionnaires subsequent to the fifth are not as reliable because of the reduced numbers of subjects involved.

With this situation in mind, all graphs and tables compiled from hourly data may be considered as meaningful only up to Test Questionnaire No. 5. Data taken from subsequent questionnaires are, however, included because of their possible interest to the reader.

HOURLY EVALUATION OF THE DEGREE OF COMFORT PROVIDED BY THE SEAT

Several implicit expectations were involved in the comfort testing situation. Quite conceivably, seat comfort evaluations made at the very beginning of a test (Test Questionnaire No. 1, at 0 hours) could serve as a basis for seat differentiation. Other factors have to be considered, however. If evaluations were restricted to the beginning of a test, the relative rates and directions of changes in opinion concerning a seat could never be determined, and much important data on the differential progression of discomfort in seats would be lost. All of these factors must be considered as acting jointly to differentiate seats according to what may be termed over-all "comfort loading."

In order to determine the rate and manner in which the comfort afforded by a seat deteriorated with protracted sitting, subjects were questioned hourly. This question (from Appendix II, page 85) was structured in the following manner:

1. What is your impression of the degree of comfort that this seat provides at the moment?

___a) It is the most comfortable seat I have ever sat in.
___b) It is extremely comfortable.
___c) It is moderately comfortable.
___d) It is mildly comfortable.
___e) It is neither comfortable nor uncomfortable.
___f) It is mildly uncomfortable.
___g) It is moderately uncomfortable.
___h) It is extremely uncomfortable.
___i) It is so uncomfortable that I cannot tolerate it.

The subject checked one of the nine descriptive statements which ranged from a highly positive statement to a highly negative statement.

For the first Test Questionnaire, the subject's choice reflected his initial impression of the seat prior to the extended sitting session. Responses to the same question on subsequent questionnaires presumably represented the cumulative effects of sitting to the point at which the questionnaire was administered.

For interpretation of this data, numbers ranging from +4 (very positive) through 0 (neither comfortable nor uncomfortable) to -4 (very negative) were assigned to the nine statements. The assumption here was that statements could be considered equidistant with respect to the degree of comfort indicated. The data are presented as average hourly scores in Table 17, Appendix V, page 100 (See Appendix VIII, for a discussion of the use of rating procedures).

The average ratings for seats are plotted in Figure 5. It should be re-emphasized that implied trends after the fifth questionnaire are not as reliable as those exhibited prior to that point because of the relative numbers of subjects involved (cf. Figure 4).

From the trends and ordering of seats in Figure 5 it can be seen that simple evaluative statements expressing degrees of comfort apparently serve as useful devices for distinguishing between seats. Note that, from the start, seats are consistently ordered. The three pilot seats (Seats #6, #2, and #1) are typically assigned positive comfort values. Seats #4 and #5, the two crew seats, fall slightly lower, with statements of comfort ranging around the neutral point. Seat #X, after a slightly positive initial rating, is consistently assigned negative statements. This ordering of seats is also made apparent by comparing totals of the average hourly evaluations for the first 5 questionnaires. The totals for the seats are as follows: Seat #6, + 11.5; Seat #2, + 8.4; Seat #1, + 7.4; Seat #5, + 1.0; Seat #4, + 0.3; Seat #X, - 6.8.

The ordering of the seats by this method is essentially the same as that determined by average sitting time, and remains relatively consistent from the first through the fifth questionnaires. This suggests the possibility that the initial evaluation (in Questionnaire No. 1) may be as useful as any subsequent evaluation.

The crossovers for Seats #1 and #2, and Seats #4 and #5, reflect the high similarities previously noted from the analysis of sitting time and scale evaluation data. Seat #6 apparently retains its higher comfort-yielding characteristics throughout the entire test, since there is little change in the average scores assigned to it. Other seats show differential rates of decrement in comfort as a function of time, with comfort deteriorating rather rapidly for Seat #X up to Hour 4; the time at which Questionnaire No. 5 was given. In general, the figure shows that the higher the initial evaluation assigned to a seat, the slower the rate of decrement. This is true for all but Seat #5 which had a somewhat higher rate of decrement than would be expected from its initial evaluation.

Up to Hour 4 (Questionnaire No. 5), trends are fairly linear and indicate that in each of the seats there is a rather constant rate of decrement in comfort with time.

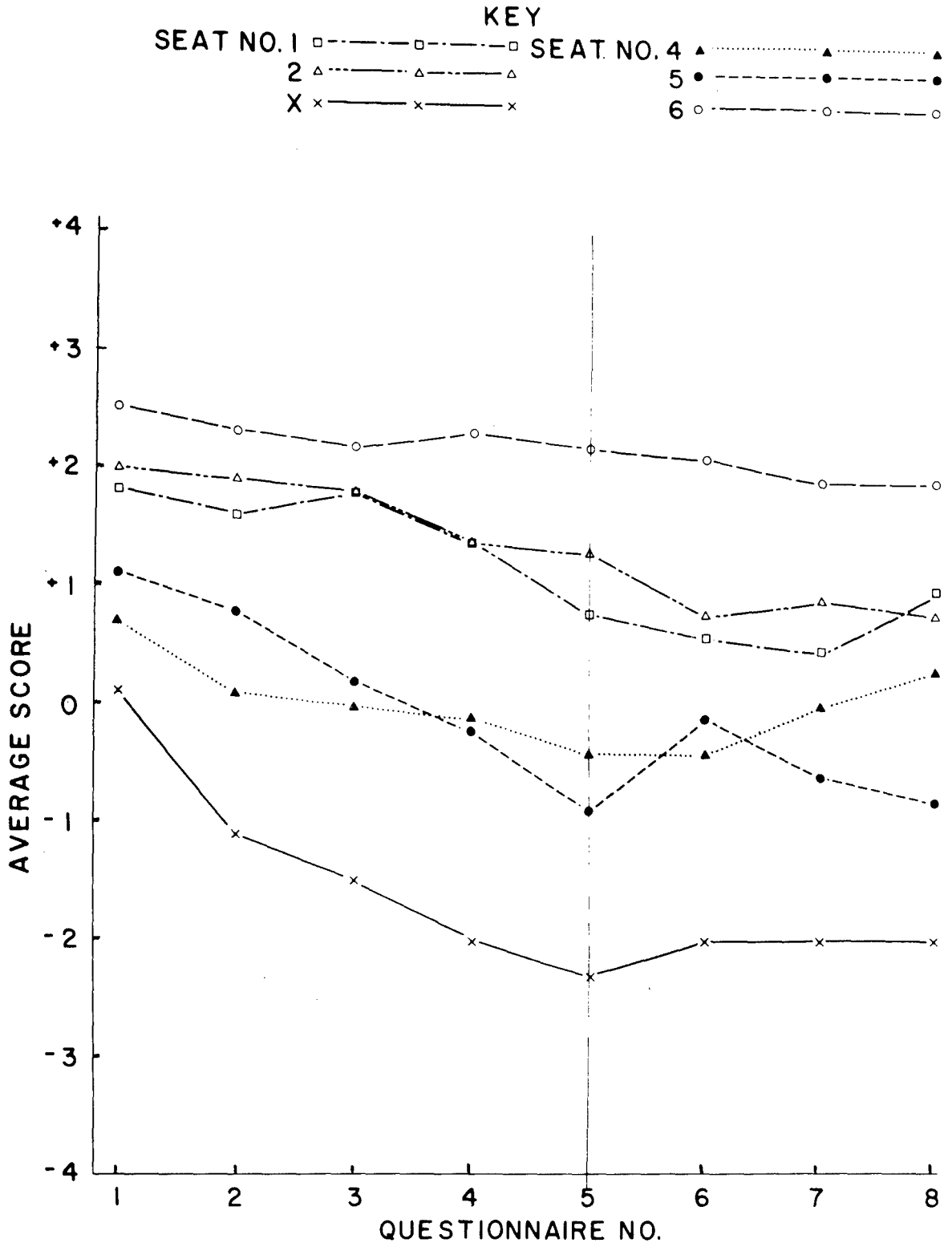

Figure 5

Hourly Evaluation of the Degree of Comfort Provided by the Seat

HOURLY PREDICTIONS OF ADDITIONAL TIME SUBJECTS ESTIMATED THEY COULD SIT

Individuals differ in tolerance for seating discomfort. In part, this can be related to physical differences between individuals (i.e. stature, weight, body type, etc.), and in part it can be related to varied psychological tolerances for discomfort.

In order to assess psychological tolerance for discomfort, the following item was included in the hourly Test Questionnaire (Appendix II, page 85):

> 2. At this moment, what is your estimate of the number of additional hours that you could sit in this seat before an intense desire to get out of it develops?
>
> _____ hours.

This approach stemmed from the concept of aspiration level. The reasoning was as follows: If an individual accurately appraises a seat, the length of sitting time initially predicted (in Questionnaire No. 1) should closely correspond to actual sitting time. Each successive appraisal furthermore, should yield an estimate that is one hour less than the appraisal given for the previous hour's questionnaire. Thus, departures of predictions from actual sitting times would mean over- or under-evaluation of the comfort-retaining characteristics of the seat.

The question is formulated to get at a subject's estimation of his capabilities for sitting in a given seat, as tempered by his knowledge concerning the attainability of sitting goals. The specific information which he brings to bear on each judgment centers around how the seat feels to him at the time of questioning. The question also permits an analysis of aspiration/performance differences among subjects on a given seat.

Information on the predictability of the comfort-retaining characteristics of a seat leads to several interesting considerations. These may be variously stated as follows: (1) Can immediate goals be established on the basis of initially felt comfort? (2) Does discomfort in a given seat rise with time to a level which alters the subject's initial goal? (3) Are such possible changes of goal related to the individual seat? It is not the intent of this study to furnish answers to all of the above questions. The questions instead are a product of pondering the data from this questionnaire item which was designed to tap levels of aspiration.

For purposes of this report, estimations of the numbers of additional hours which subjects could sit are treated only in terms of group measures (i.e. average hourly estimation of sitting time at each questionnaire).

For interpretation of the data, the hourly predictions of the additional number of hours that a given seat could be tolerated were averaged over subjects and plotted in Figure 6. (The averages as well as the numbers of individuals giving a response on each questionnaire are presented in Table 18, Appendix VI, page 101.)

Trends in Figure 6 are fairly clear and seats are clearly differentiated up to Test Questionnaire No. 5. Thereafter "dead-end" subjects, sticking out the test in

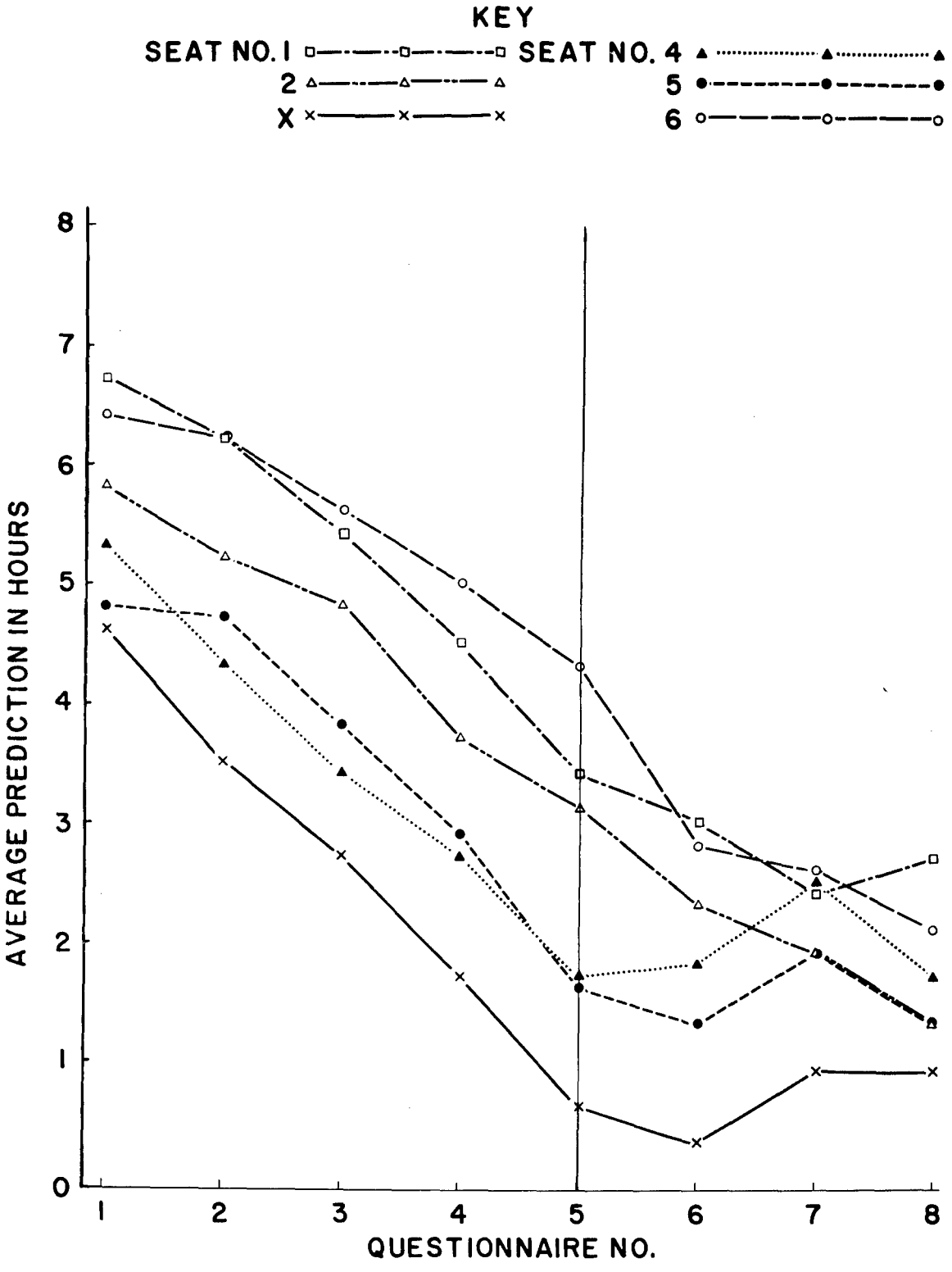

Figure 6

Average Hourly Predictions of Additional Time
Subjects Estimated They Could Sit

uncomfortable seats, destroy what would otherwise be a relatively linear trend for each seat. Initial predictions were accurate (indicated by slope and linearity of the curves) for Seats #1, #2, #4, and #X. After about an hour, however, initial predictions for Seats #6 and #5 had to be revised downward. Thus, Seats #6 and #5 seemed at first as though they were going to remain more comfortable than they actually became later.

The graph gives additional evidence of the clustering of certain seats. The pilot seats (Seats #1, #2, and #6) retain their higher ratings. The crew seats (Seats #4 and #5) rank closely and Seat #X ranks lowest. Ordering of the seats at the time Test Questionnaire No. 5 was given agrees well with the ranking found with sitting time data (cf. Figure 1). If the average hourly estimations calculated for Test Questionnaire Nos. 1 to 5 are summed, these totals may serve as further indices for differentiating the seats. Using these indices, the seats rank as follows: Seat #6, 23.6; Seat #1, 23.2; Seat #2, 19.9; Seat #5, 16.6; Seat 4, 16.1; Seat #X, 12.9.

HOURLY PROGRESSION OF SPECIFIC BODY DISCOMFORT

The manner in which discomfort progresses in particular body regions during long periods of sitting may be assumed to depend directly upon the seating configuration. Although general discomfort undoubtedly develops after a time in any seat irrespective of its degree of comfort, it may be expected that structural peculiarities differentially affect the progression of discomfort in particular body regions in contact with the seats.

The following question (Appendix II, page 85) was designed to follow the hourly progression of discomfort in pertinent body regions:

1. Describe the degree of discomfort that you feel at this time in the following body regions.

	None	Slight	Moderate	Severe	Very Severe	Intolerable
a) Neck	___	___	___	___	___	___
b) Shoulders	___	___	___	___	___	___
c) Back	___	___	___	___	___	___
d) Buttocks	___	___	___	___	___	___
e) Thighs	___	___	___	___	___	___
f) Legs	___	___	___	___	___	___

For the interpretation of the data, numbers ranging from 0 (none) to 5 (intolerable) were assigned to the six degrees of discomfort. The assumption here was that the terms could be considered equidistant with respect to degree of discomfort. The numbering of categories was used for describing trends (See Appendix VIII, page 111 for discussion of the use of scales in this study.)

Average hourly scores were calculated for each questionnaire presentation, for each seat, and for each body region (Appendix VII, page 102 to 110). Totals of the average scores for each of the first 5 questionnaires were also calculated for use as indices in ranking.

The Neck

Average hourly discomfort scores for the neck are presented graphically in Figure 7 (cf. Table 19, Appendix VII, page 102).

It can be seen that, in general, differences between seats in the progression of discomfort in the neck are not outstanding. However, there was a tendency for neck discomfort to increase progressively. Seats #4 and #5, the crew seats, and Seat #X, in general caused more discomfort than Seats #1, #2, and #6, the pilot seats. This can also be seen by comparing the sums of the average hourly scores for the first five questionnaires (see Table 19, Appendix VII, page 102). These totals rank the seats as follows: Seat #6, 0.8; Seat #2, 1.0; Seat #1, 1.2; Seat #X, 1.7; Seat #4, 1.8; and Seat #5, 2.0.

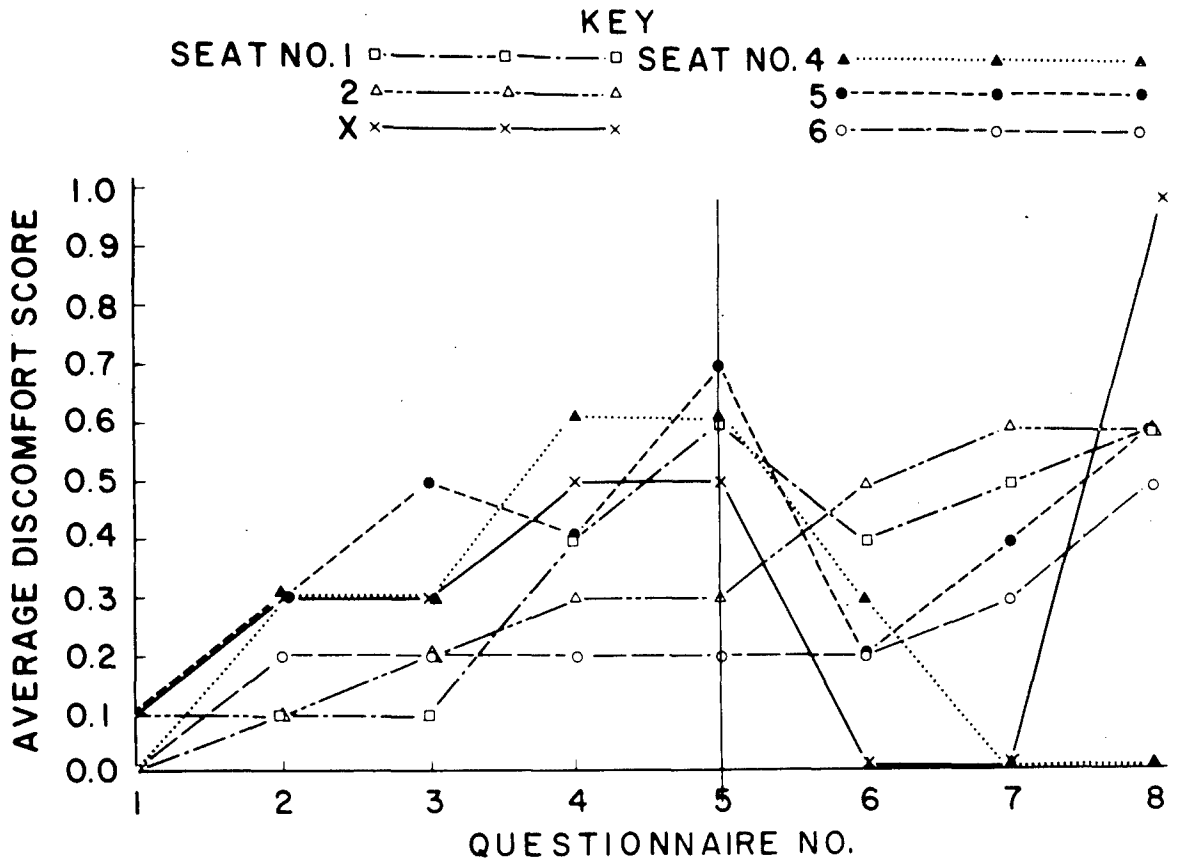

Figure 7

Average Hourly Discomfort in the Neck

The outstanding differences between crew and pilot seats in general are that the pilot seats have headrests, armrests, and adjustable backs, while the crew seats do not. One of the crew seats, Seat #5 (Figure 21, page 73), does have a headrest. The other, Seat #4 (Figure 20, page 71), does not. Seats #4 and #5 afforded the most discomfort to the neck. On the other hand, Seat #6 (Figure 22, page 75), a pilot seat with no headrest, afforded the least neck discomfort. From these

considerations it seems that presence or absence of headrests had little or nothing to do with neck discomfort. Since pilot and crew seats are differentiated in terms of neck discomfort, some structural features shared by pilot seats but not found in crew seats (or vice versa) likely is causal. Neck discomfort in the crew seats might be due to lack of adjustability and/or armrests.

Since the rank ordering of seats in terms of neck discomfort does not correspond with that determined by the previously described methods, we may tentatively assume that neck discomfort was not an important factor in the evaluation of general seat comfort.

The Shoulders

Average hourly discomfort scores for the shoulders are presented graphically in Figure 8 (cf. Table 20, Appendix VII, page 103).

The graph shows that for the first 5 questionnaires, shoulder discomfort was hardly a factor at all in the pilot seats. However, the crew seats did cause some shoulder discomfort. Again, this probably can be related to the fact that the crew seats lack back adjustability and armrests.

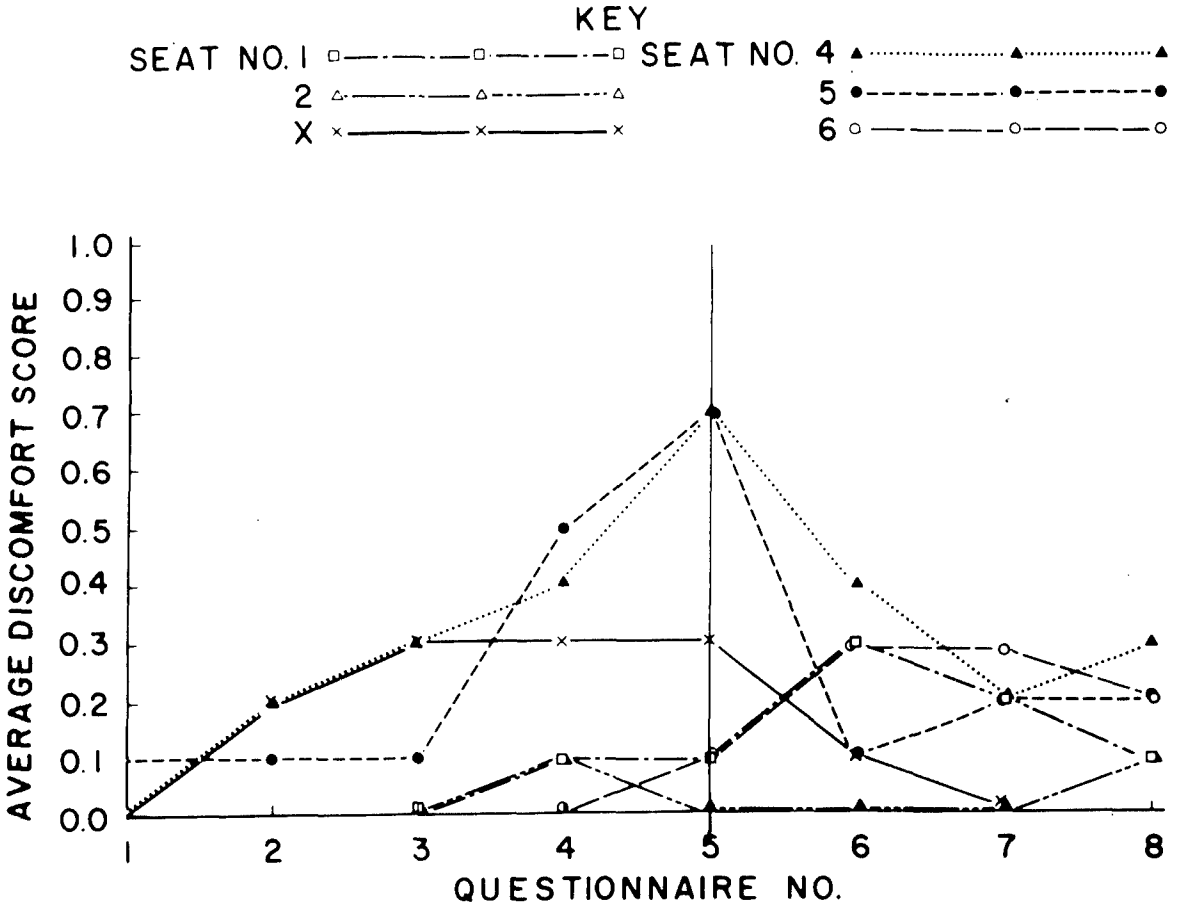

Figure 8

Average Hourly Discomfort in the Shoulders

Although neck and shoulder discomfort are undoubtedly related, it can be seen by comparison of Figures 7 and 8 that in the more comfortable seats (#1, #2, and #6), neck discomfort begins considerably earlier than does shoulder discomfort.

Sums of average hourly discomfort in the shoulders for the first 5 questionnaires are as follows: Seat #6, 0.1; Seat #2, 0.1; Seat #1, 0.2; Seat #X, 1.1; Seat #5, 1.5; Seat #4, 1.6. As in the case of the neck, rank ordering of the seats in terms of shoulder discomfort suggests that the latter was not particularly important in the determination of general seat comfort.

The Back

Average hourly discomfort scores for the back are presented graphically in Figure 9 (cf. Table 21, Appendix VII, page 104). As can be seen, the magnitude of back discomfort in each seat is considerably greater than that reported for the neck or the shoulders. Pilot and crew seats, furthermore, are very clearly differentiated in terms of basic discomfort, indicating the great importance of adjustability in the alleviation of back discomfort.

Not only are the crew seats differentiated from the pilot seats, but Seat #X is set apart from Seats #4 and #5. This is very likely due to the fact that Seat #X is unpadded and made of wood. However, the possibility also exists that the fixed angle between seat pan and back is a contributing factor. As can be noted from the legends accompanying Figures 19, 20, and 21, pages 69 to 73, the seat pan and back angles from the horizontal in Seats #X, #4 and #5 are respectively 9° and 109°, 7° and 102°, and 2° and 100°. The relatively greater angles in Seat #X put the subject in a more reclining position so that more of the body weight rests on the seat back. Thus it is possible that the combined factors of lack of cushioning and a more reclined back are responsible for the magnitude of back discomfort reported for Seat #X.

Comparison of the totals of average hourly scores for the first 5 questionnaires ranks the seats as follows: Seat #6, 1.2; Seat #1, 1.6; Seat #2, 1.8; Seat #4, 3.4; Seat #5, 3.6; Seat #X, 5.7. By examination of these indices and the curves in Figure 9, it can be seen that the rank ordering of the seats in terms of back discomfort closely approximates that determined by sitting time, scale evaluation, etc. This then suggests that back discomfort was an important factor to the subjects in their evaluation of the seats.

The Buttocks

Average hourly discomfort scores for the buttocks are presented graphically in Figure 10 (cf. Table 22, Appendix VII, page 105). The graph shows that buttocks discomfort was greater in magnitude and importance than was discomfort in any of the body regions thus far discussed. Although pilot and crew seats are not clearly differentiated, there is a clear demarcation between the crew seats.

Buttocks discomfort would presumably be associated with the type of cushioning provided by the seat. Seat #X, in agreement with this hypothesis, caused the greatest discomfort. However, Seat #5 which was cushioned, caused very nearly as much discomfort as did uncushioned Seat #X, and considerably more than any of the other four cushioned seats.

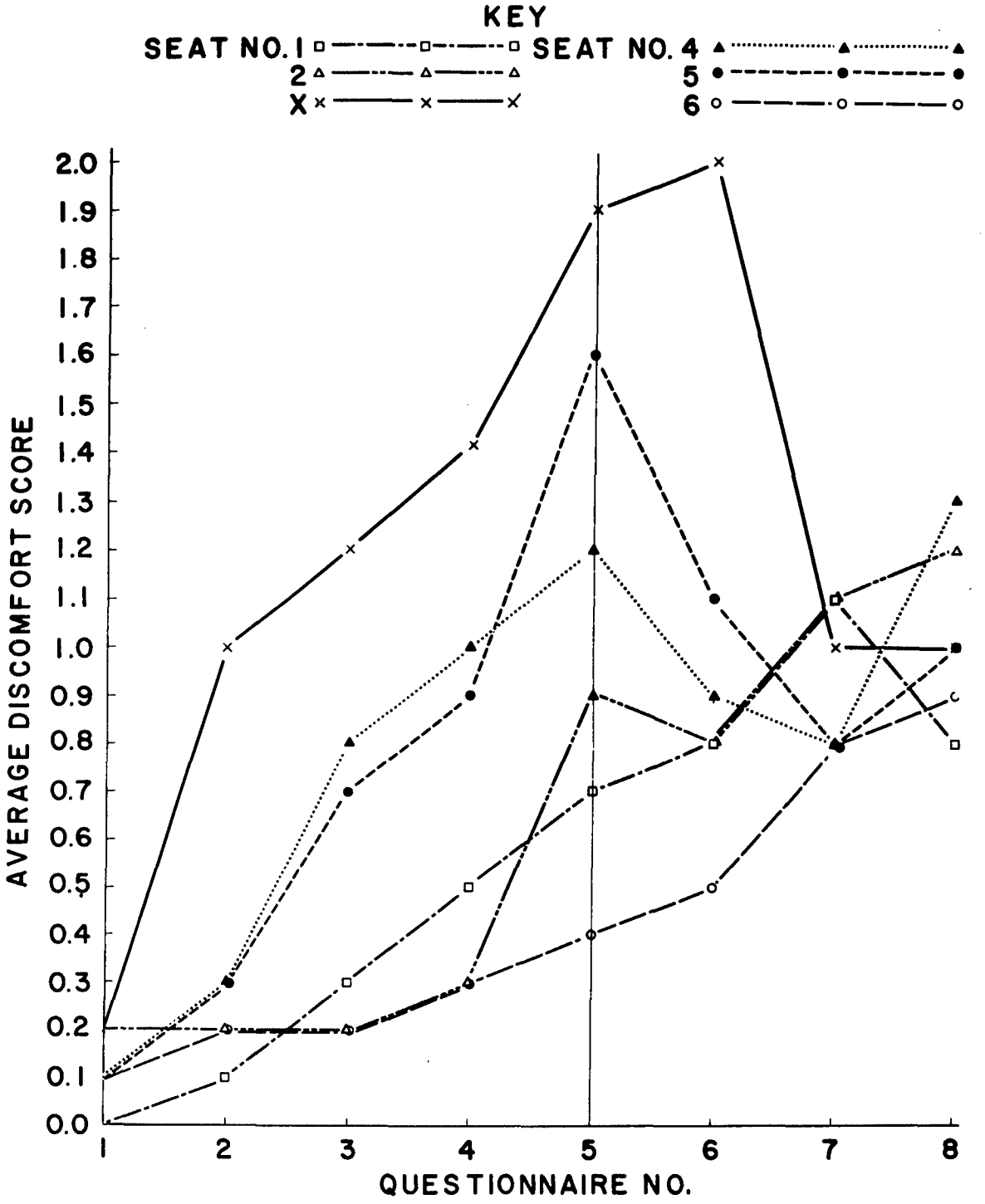

Figure 9

Average Hourly Discomfort in the Back

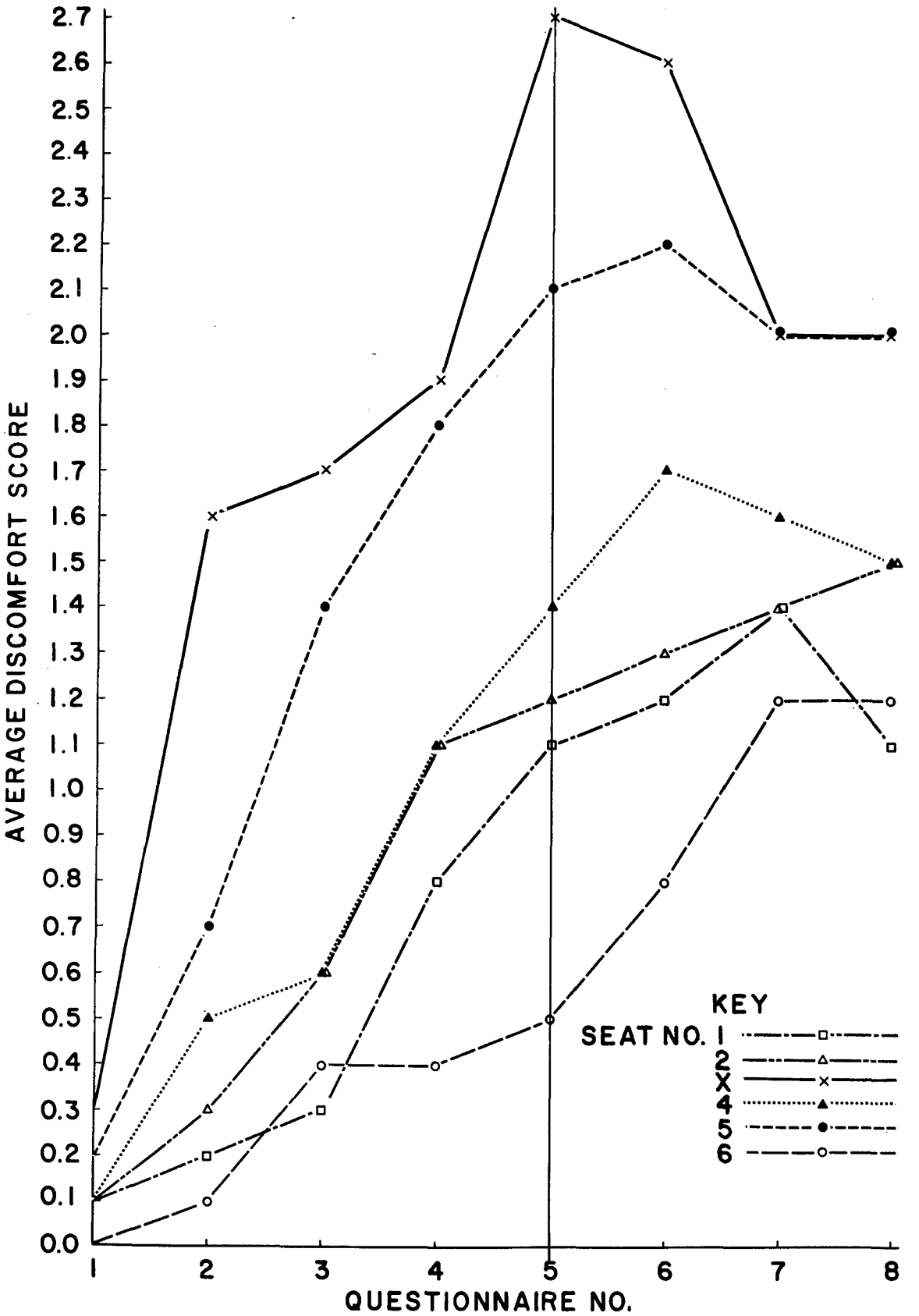

Figure 10

Average Hourly Discomfort in the Buttocks

Furthermore, the only marked differences between Seat #4 and #5 (with reference to parts in contact with the buttocks) is in type of cushioning. Yet Seat #5 afforded considerably more discomfort to the buttocks than did Seat #4. This most certainly indicates that the cushioning in Seat #5 is defective in its comfort qualities, a matter which will be discussed further in a later section of this report. It further suggests that even though a seat is cushioned, if the cushioning is improper, it may be nearly as detrimental to comfort as complete lack of cushioning.

Although the differences between Seats #4, #1 and #2 are slight, Seat #6 is the most comfortable for the buttocks as it is for the body regions already discussed.

If totals of the average hourly scores from the first 5 questionnaires are used as indices, ranking of the seats is as follows: Seat #6, 1.4; Seat #1, 2.5; Seat #2, 3.3; Seat #4, 3.7; Seat #5, 6.2; Seat #X, 8.2.

Inspection of these indices and Figure 10 indicates that the rank ordering of the seats according to buttocks discomfort is very similar to the ranking by other methods in this study. It is obvious that buttocks discomfort was an important determining factor in evaluations of the seats.

The Thighs

Average hourly discomfort scores for the thighs are presented graphically in Figure 11 (cf. Table 23, Appendix VII, page 106).

In general, thigh discomfort was relatively negligible in the pilot seats (#1, #2, and #6). Although crew and pilot seats are not clearly differentiated by this method, comparatively more thigh discomfort was experienced in the former. Seat #4, however, caused an inordinate amount of discomfort, indicating that it possesses a structural peculiarity detrimental to thigh comfort. Inspection of Figure 20, page 71, will reveal that Seat #4 possesses a bar-type thigh pad which unquestionably was largely responsible for the thigh discomfort. However, discomfort caused by the thigh pad is also dependent on the height of the seat pan from the floor. If the seat could be adjusted low enough so that the subject's feet were firmly on the floor, the thighs could be held off the thigh pad. However, vertical adjustment of the seat is inadequate, making it impossible in most cases to lower the seat enough to take the full weight of the thighs and lower legs off the thigh pad. This inadequacy of vertical adjustment will be discussed later.

Thigh pads of a different type, (i.e., more flexible and separated) are found on Seats #1 and #2 (cf. Figures 17 and 18, pages 65 and 67). These thigh pads in combination with adequate ranges of vertical adjustments caused practically negligible discomfort in the thighs.

Another factor in thigh discomfort is the length of the seat pan. Seats #1, #2 and #6 (the pilot seats), which provided the most comfort to the thighs, had seat pans 17, 18½ and 19 inches in length, respectively. Thigh pads were present only in Seats #1 and #2. The uncushioned condition in Seat #X certainly must be considered, but the shortness of the seat pan (only 15") also probably contributed to thigh discomfort as well as did the fixed height and the seat pan angle of 9°. The seat cushion of Seat #5 is only 13-3/4" in length. This shortness, compounded with the inadequate cushioning previously discussed, was very likely responsible

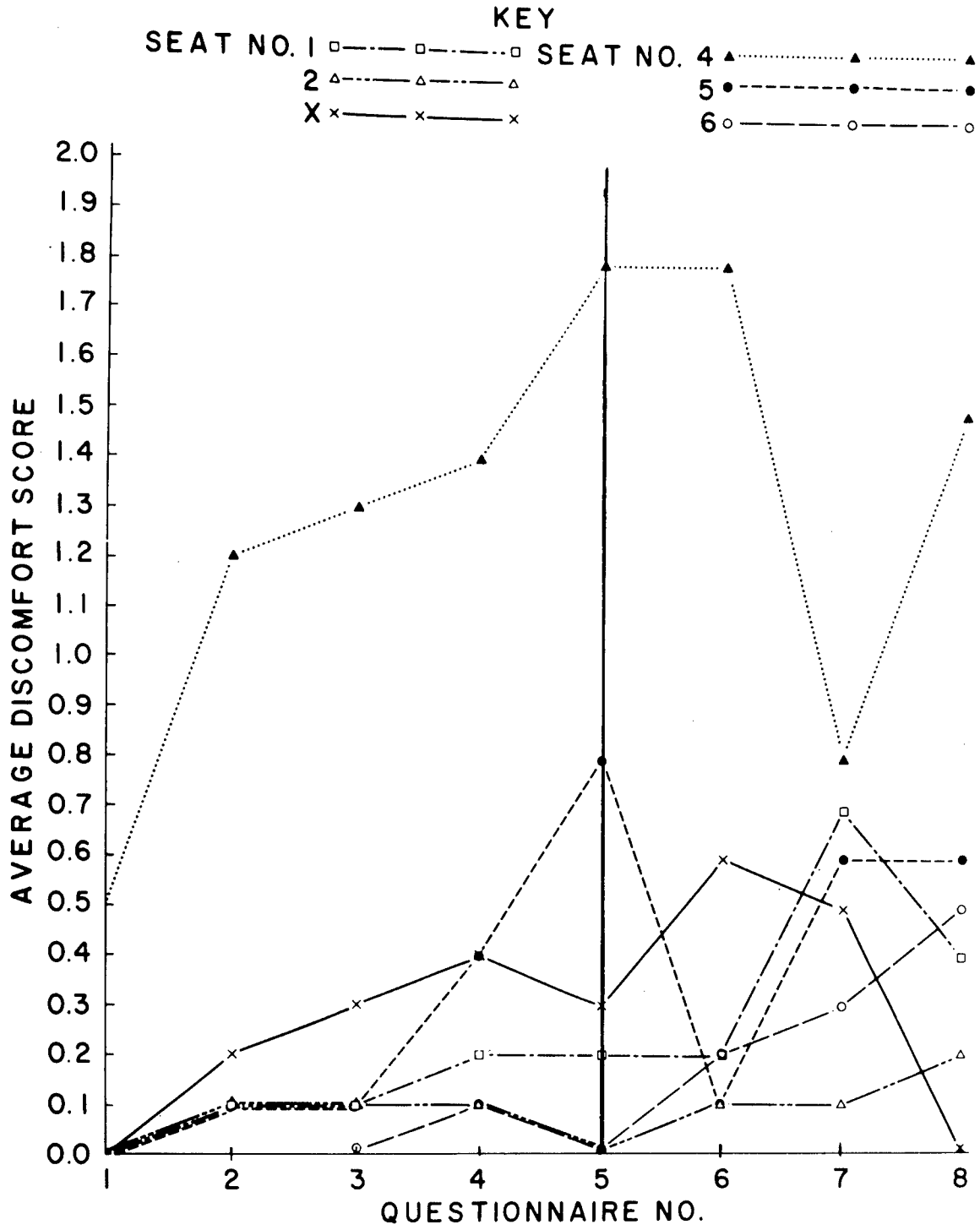

Figure 11

Average Hourly Discomfort in the Thighs

for the discomfort reported. It is therefore indicated that essentially three factors were involved in thigh discomfort. They were: poorly designed thigh pads compounded with inadequacy of vertical adjustment; angle and shortness in length of the seat pan, and improper cushioning.

Ranking of the seats in terms of thigh discomfort indicates that except for Seat #4, thigh discomfort was not an important factor influencing the general evaluation of the seats. The totals of the average hourly scores for the first 5 questionnaires (Table 23, Appendix VII, page 106) are as follows: Seat #6, 0.1; Seat #2, 0.3; Seat #1, 0.6; Seat #X, 1.2; Seat #5, 1.4; Seat #4, 6.2.

The Legs

Average hourly discomfort scores for the lower legs are presented graphically in Figure 12 (cf. Table 24, Appendix VII, page 107).

In general, lower leg discomfort does not appear to be an important factor. Crew and pilot seats are not differentiated.

Seats #4 and #5 appear to offer somewhat more discomfort to the lower legs than that caused by the other seats. This is more than likely associated with the same factors which caused discomfort in the thighs (improper cushioning, shortness of seat pan, and thigh pads).

It should be noted that the sharp rise of the curve for Seat #X after the fifth questionnaire is based on data from only one subject and therefore cannot be considered as a trend.

Totals of the average hourly scores for the first 5 questionnaires are as follows: Seat #6, 0.3; Seat #X, 0.4; Seat #1, 0.6; Seat #2, 0.6; Seat #5, 1.0; Seat #4, 1.7. Again, discomfort in the lower legs does not appear to have been an important factor in the general evaluation of seat preference.

TOTAL AVERAGE HOURLY DISCOMFORT IN EACH BODY REGION

In order to examine the relative importance of each body region in the development of discomfort, data from all of the seats were combined. Thus, for each questionnaire given, the average hourly discomfort scores (first five questionnaires) for each body region were summed over all of the seats (cf. Table 25, Appendix VII, page 108). These totals of average hourly discomfort scores for each body region are presented graphically in Figure 13.

The graph shows that the buttocks and back are by far the most important areas in the development of seating discomfort. Ranking next are the neck and thighs, which appear to be nearly equal in importance. The slightly higher scores for the thighs are very likely due to the inordinate amount of discomfort that was experienced in Seat #4 (cf. Figure 20, page 71). The least discomfort was experienced in the legs and shoulders, indicating that these body regions were not critical.

If the scores for the first 5 questionnaires (used in Figure 13) are summed for each body region, ordering of the body regions is as follows: buttocks, 25.3; back, 17.3; thighs, 9.8; neck, 8.5; shoulders, 4.6; lower legs, 4.6.

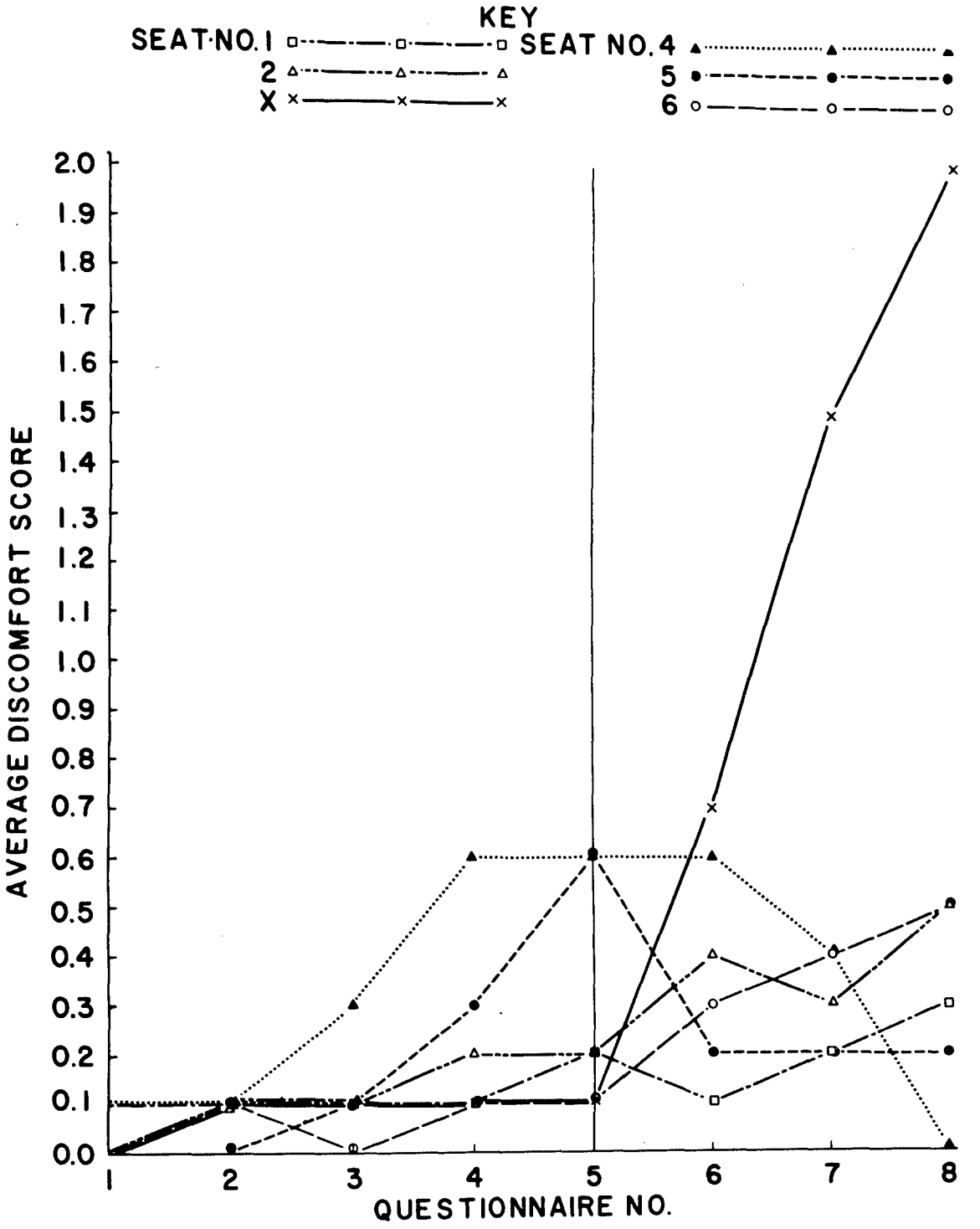

Figure 12

Average Hourly Discomfort in the Legs

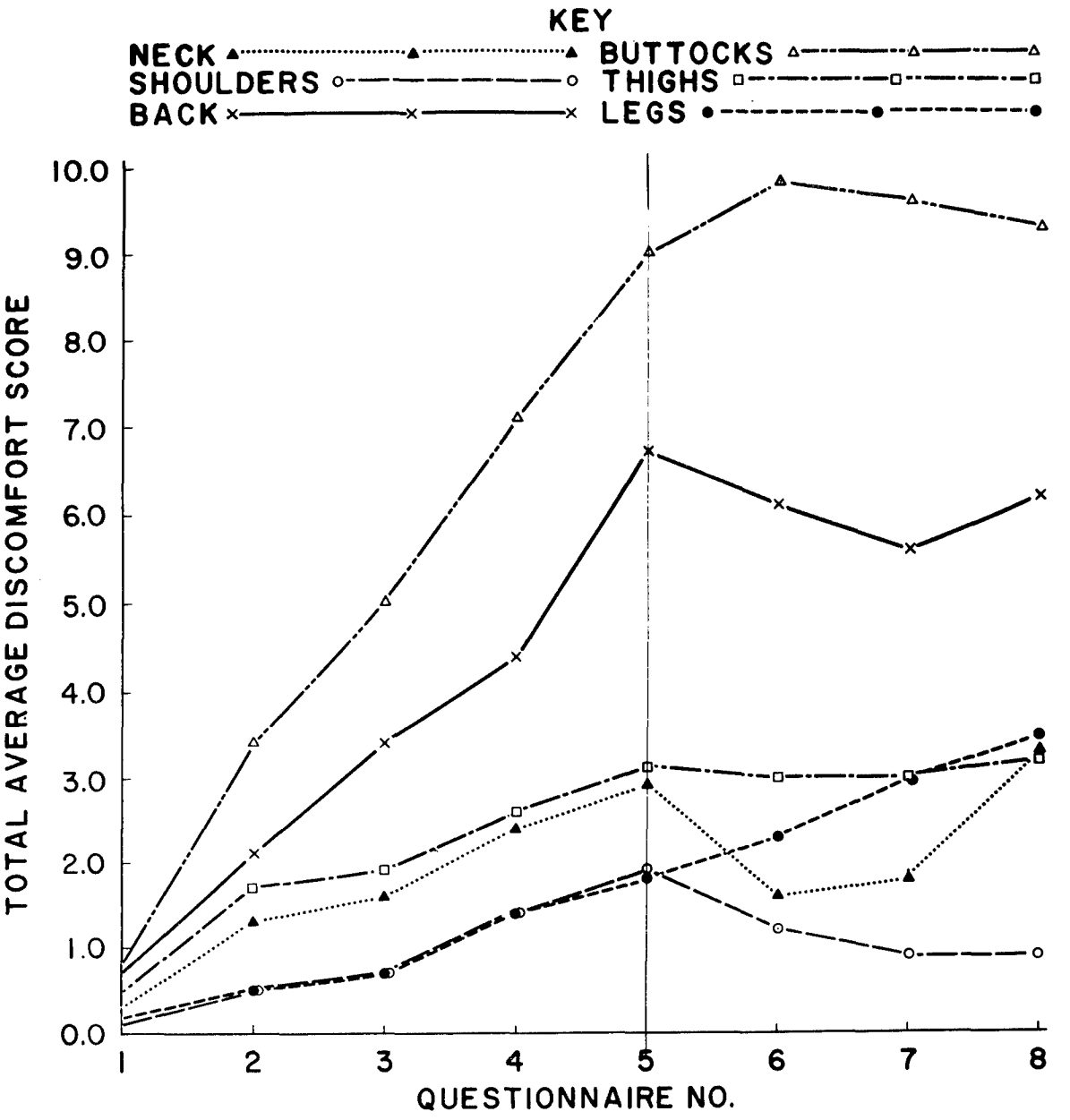

Figure 13

Total Average Hourly Discomfort in Each Body Region

TOTAL AVERAGE HOURLY DISCOMFORT IN EACH SEAT

The average hourly discomfort scores obtained for the various body regions were pooled to yield an index of over-all discomfort for each seat (cf. Table 26, Appendix VII, page 109). The total average hourly discomfort scores thus determined are shown as a function of questionnaire in Figure 14. It is immediately apparent that crew and pilot seats are clearly differentiated with respect to the total average discomfort they afforded.

If the scores used in the graph (Figure 14) are summed over the first five questionnaires for each seat (Table 26, Appendix VII, page 109), the totals order the seats as follows: Seat #6, 3.9; Seat #1, 6.7; Seat #2, 7.1; Seat #5, 15.7; Seat #X, 18.3; Seat #4, 18.4. It can be seen that the ranking of seats by this method differs somewhat from rankings determined by other more general methods.

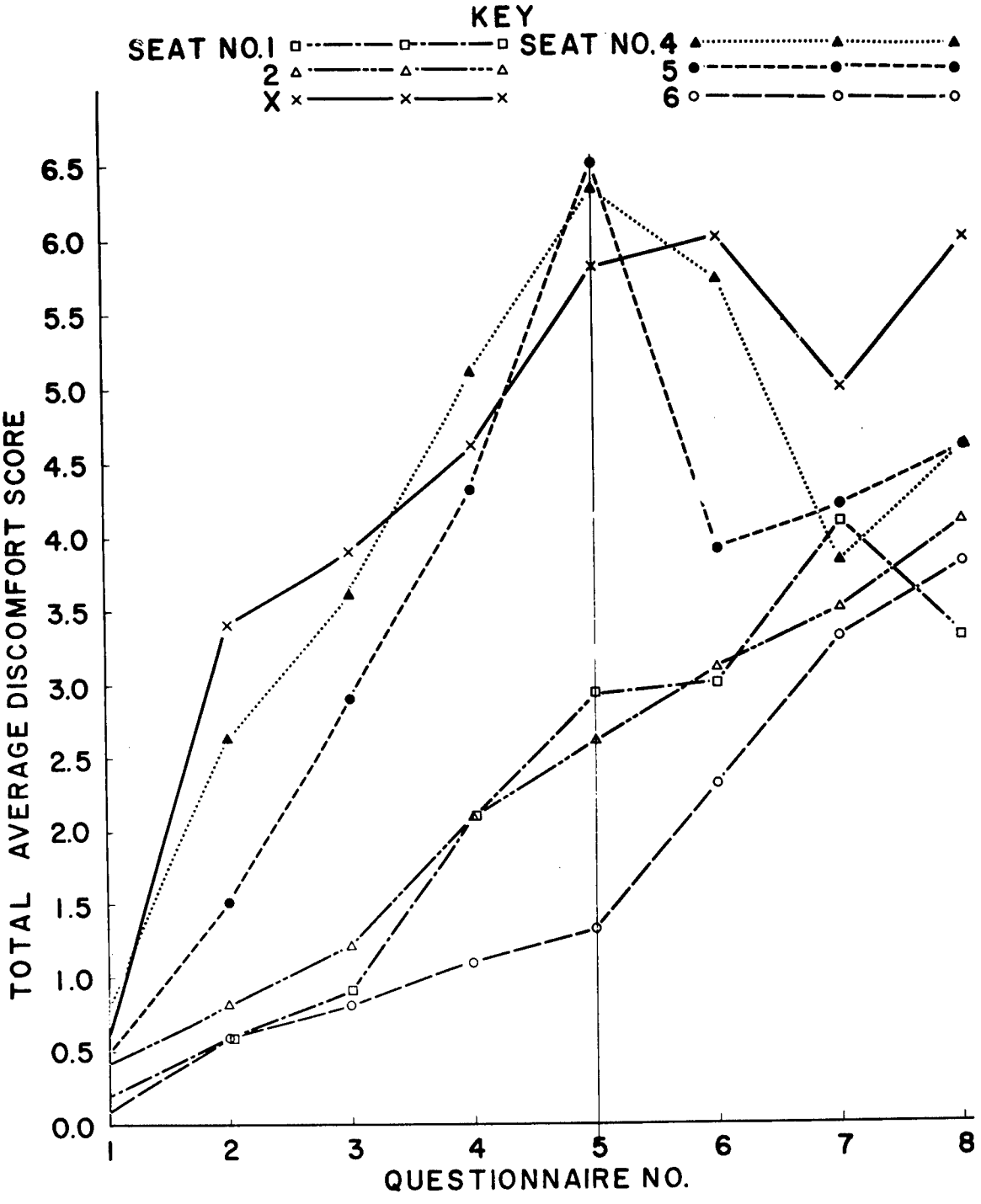

Figure 14

Total Average Hourly Discomfort in Each Seat

In this case, Seats #X and #4 are little different whereas by other methods Seat #X was generally ranked lowest (cf. Figures 1, 3, 5, 6). In explanation, two possibilities are suggested: (1) When using general methods in evaluating Seat #X, the subjects may have reacted to the seat's crude appearance and thus ranked it lower than actual discomfort would have dictated; (2) When using general methods to evaluate Seat #4, the subjects may have considered the extreme discomfort caused by the thigh pads as a "special" feature and thus tended to overlook it in general evaluations of the seat.

TIME OF ONSET OF DISCOMFORT

Comparison of the times at which discomfort begins in the various body regions would presumably reveal the relative sensitivities of the areas in the development of discomfort. Data concerning the times at which discomfort in each body region was first reported were taken from the hourly questionnaires. These times were then averaged for each seat, giving the average times of onset of discomfort in each body region for each seat. These average times of onset of discomfort in minutes from the beginning of the test are shown graphically in Figure 15 (cf. Table 27, Appendix VII, page 110).

In general, discomfort in each of the body regions began sooner in Seats #4, #5, and #X, than in Seats #1, #2, and #6. If the times of onset of discomfort in minutes are averaged over all body regions for each seat, the ordering of the seats is as follows: Seat #6, 220.0; Seat #1, 198.0; Seat #2, 189.2; Seat #5, 134.5; Seat #4, 112.6; Seat #X, 99.1. Thus the ranking of the seats by this method gives an order agreeing closely with that determined by methods previously discussed.

If the times of onset of discomfort in minutes from beginning of the test are averaged over all seats for each body region (Table 27, Appendix VII, page 110), the ranking of the body regions is as follows: buttocks, 121.2; back, 147.4; thighs, 159.0; neck, 164.7; shoulders, 191.0; legs, 206.8. This ordering of the body regions agrees very closely with that determined by summing average hourly discomfort scores for each body region (cf. Figure 13 and page 36). This close agreement suggests that the average time of onset of discomfort in each body region is a good indicator of the relative importance of that body region in the development of discomfort during protracted sitting.

It might be mentioned here that, had the testing procedure been designed so that all subjects were required to sit the full seven hours, it would have been possible to interpret peaks and durations of discomfort as well as times of onset. This procedure would undoubtedly have given additional basic information about the progress of discomfort for subjects in the series of seats. However, if such a procedure was used, lengths of voluntary sitting time could not be used as a measure of seat preference.

TYPES OF DISCOMFORT

In order to supplement data concerning the degrees of discomfort developed with protracted sitting, an exploratory attempt was made to assemble qualitative information about the nature of this discomfort. The following question (Appendix II, page 85) was designed for this purpose:

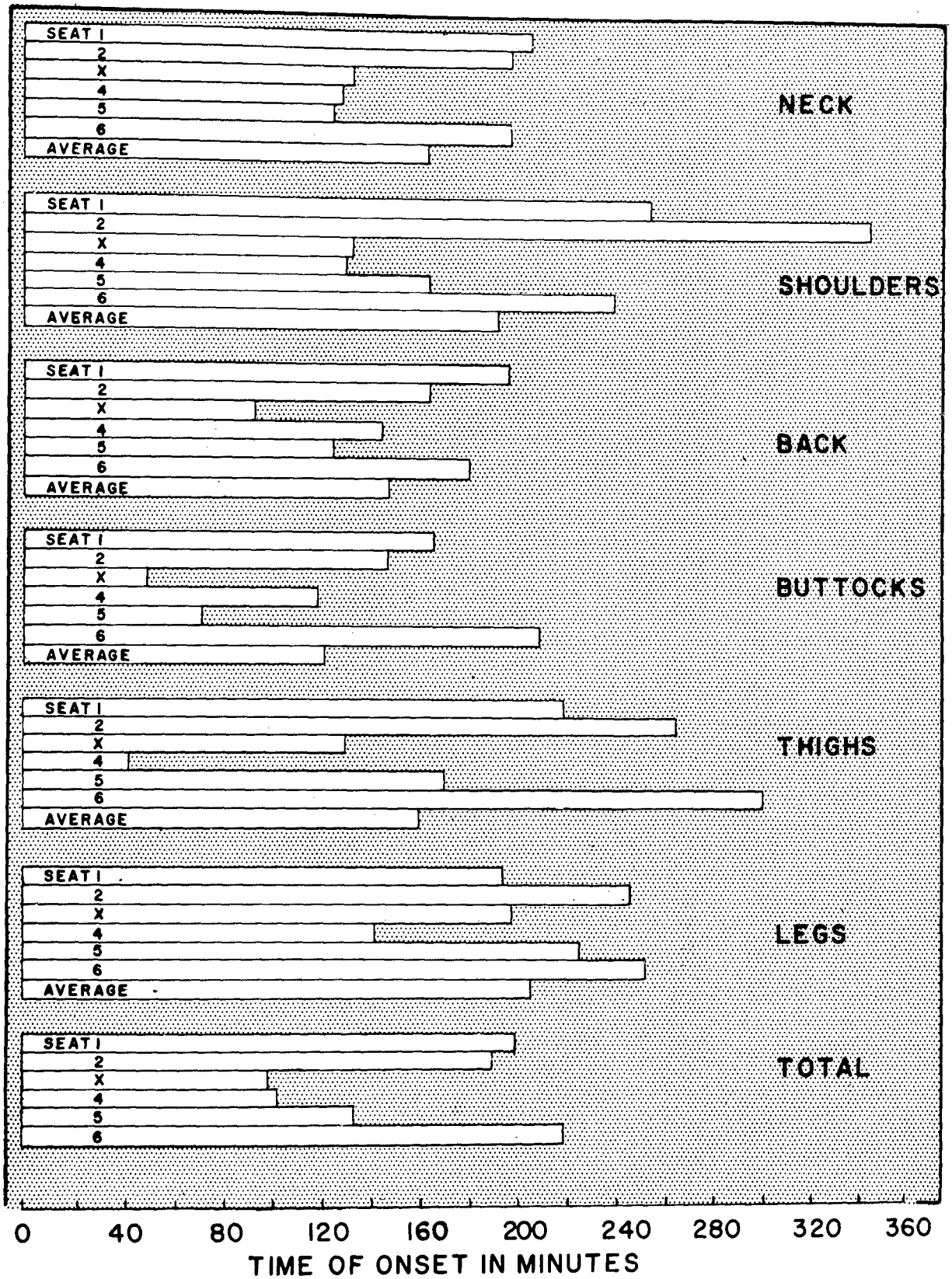

Figure 15

Average Times of Onset of Discomfort

2. Describe the sensations you feel in the following body regions. If none of the sensations listed apply to a particular region, leave a blank.

	Excessive Pressure	Stiffness	Ache	Soreness	Prickling Sensation	Numbness
a) Neck						
b) Shoulders						
c) Back						
d) Buttocks						
e) Thighs						
f) Legs						

The rationale behind the selection of the terms describing the types of discomfort likely to occur during protracted sitting was that, empirically, these terms are associated with essentially three different origins of body discomfort. Presumably "excessive pressure" is associated with superficial sensations originating in the skin and underlying tissues and caused by contact with parts of the seat. "Stiffness," "ache" and "soreness" would describe discomforts originating in the deeper-lying body parts such as the muscles and joints which would be involved in postural discomfort. "Prickling Sensation" and "numbness" would be associated with pressures caused by contact with the seat which are great enough to interfere with the circulation of blood in certain body regions.

It was expected that information gained from this question might be useful in the following ways: (1) to serve as a check on the previous question which was concerned with the degrees rather than the types of discomfort; (2) to give basic information about the types of discomfort most frequently associated with each body region; (3) to serve as an additional method for ranking the seats.

The data derived from this question were treated in terms of frequencies of types of discomfort reported in the first five questionnaires.

Table 3 presents the frequencies of types of discomfort reported for each body region. If the totals for each body region are examined, it can be seen that the body regions may be ranked in order of decreasing importance as follows: buttocks, 298; back, 178; thighs, 112; neck, 106; shoulders, 56; legs, 49. Comparison of Table 3 with Figures 13 and 15, pages 38 and 41, reveals that this method of ranking the body regions agrees very closely with the methods using totals of average hourly discomfort scores and times of onset of discomfort.

Table 3 also reveals certain information about types of discomfort. If the total numbers of reports of each type of discomfort are examined, it can be seen that the types of discomfort in order of decreasing frequency are as follows: excessive pressure, 201; stiffness, 169; soreness, 166; ache, 155; numbness, 59; prickling sensation, 49. This suggests that, in general, superficial sensations in the skin (excessive pressure) constitute the most prevalent type of seating discomfort. Deeper-lying discomfort in the muscles and joints (stiffness, ache and soreness) is also frequently experienced. Discomforts caused by interference with blood circulation (prickling sensation and numbness) are least important.

The data in Table 3 also suggest the extent to which each type of discomfort is associated with each body region. Excessive pressure is experienced mainly in the back, buttocks and thighs - the body areas in closest contact with the seat.

Table 3

Number of Times Each Type of Discomfort was Reported for each Body Region (first 5 questionnaires)

Type of Discomfort	Neck	Shoulders	Back	Buttocks	Thighs	Legs	Total
Excessive Pressure	6	5	22	116	45	7	201
Stiffness	60	26	51	3	8	21	169
Ache	32	11	66	17	21	8	155
Soreness	8	14	38	79	21	6	166
Prickling Sensation	0	0	1	35	8	5	49
Numbness	0	0	0	48	9	2	59
Totals:	106	56	178	298	112	49	

Stiffness is most commonly felt in regions concerned with postural support. Ache is experienced primarily in the neck and back. Soreness is experienced mainly in the back and buttocks. The high frequency of soreness in the buttocks, considered together with the fact that excessive pressure is also frequently experienced in the buttocks, might suggest that the feeling of soreness involves both superficial sensations and deeper-lying body discomfort. Prickling sensation and numbness are experienced primarily in the buttocks, suggesting that excessive pressure caused a certain amount of interference with the circulation in this area.

It must be remembered that these speculations are based upon a series of assumptions. Whether or not these considerations are valid depends largely upon the meanings that terms describing discomfort have to subjects and the relation of these terms to physiological phenomena. In any case, it is obvious that there are abundant problems in this area for the future investigator.

Table 4 presents the frequencies of types of discomfort reported on each seat. According to this method, the seats are ranked as follows: Seat #6, 59; Seat #1, 81; Seat #2, 96; Seat #4, 186; Seat #X, 188; Seat #5, 189. This method of ranking does not appear to be as sensitive as some others, but the pilot seats (#1, #2,

Table 4

Number of Times Each Type of Discomfort was Reported on Each Seat (first 5 Questionnaires)

Type of Discomfort	Seat #1	Seat #2	Seat #X	Seat #4	Seat #5	Seat #6	Total
Excessive Pressure	24	27	48	47	42	13	201
Stiffness	20	24	35	35	45	10	169
Ache	17	15	31	42	33	17	155
Soreness	9	24	45	35	39	14	166
Prickling Sensation	2	4	10	16	14	3	49
Numbness	9	2	19	11	16	2	59
Totals:	81	96	188	186	189	59	

and #6) are clearly differentiated from the crew seats (#4 and #5) and from the control seat #X.

EVALUATION OF SEAT PARTS

Hourly Evaluation

Included in the Test Questionnaire (Appendix II, pages 86 to 87) were a series of questions designed to gain specific evaluations of several structural characteristics of each seat. The subjects were asked to evaluate the seat cushions, the back cushions, the headrest, and the armrests in terms of several characteristics of each. The questions were structured in a manner similar to the following example:

3. Evaluate the following characteristics of this seat. Put a check mark next to the statement which applies.

   1. Seat cushion:

      a) The seat cushion is:
      ____ too firm
      ____ just right
      ____ too soft

      b) The seat cushion is:
      ____ too wide
      ____ just right
      ____ too narrow

      c) The seat cushion is:
      ____ too long
      ____ just right
      ____ too short

This series of questions was administered hourly for three reasons: (1) to keep the subject highly aware of factors contributing to his state of comfort; (2) to follow possible changes in opinion about the characteristics of the seat; (3) to gain more specific information about the particular characteristics of each seat which were responsible for the discomfort afforded.

During analysis of the data it soon became obvious that there was little tendency for opinion to change with time; i.e., once a subject had formed an opinion he tended to retain it on each subsequent questionnaire. Therefore, the data are presented in terms of the number of subjects making a particular complaint, regardless of the number of repetitive reports in successive hourly questionnaires. Table 5 presents this information.

Certain points pertaining to the seat parts stand out from inspection of the data. The following paragraphs outline these points.

Complaints about seat cushions indicate that they vary considerably in softness, and, in certain cases, have inadequate dimensions. These criticisms were particularly applied to Seats #4 and #5. The relationships between comfort,

Table 5

Frequencies of Complaints During Hourly Evaluations of Seat Parts

Seat Part	Complaints	Seat #1 16 Subj.	Seat #2 18 Subj.	Seat #X 18 Subj.	Seat #4 16 Subj.	Seat #5 17 Subj.	Seat #6 17 Subj.
SEAT CUSHION	Too firm	3	7	17	4	3	2
	Too soft	5	1	0	5	12	2
	Too narrow	2	1	1	5	4	0
	Too wide	0	1	0	0	0	0
	Too short	5	3	9	7	13	0
	Too long	0	1	0	1	0	1
	Excessive Pressure:						
	On buttocks	9	11	16	12	14	6
	On thighs	4	2	4	14	5	2
	On base of spine	4	5	5	4	5	0
BACK CUSHION	Too firm	3	7	16	3	1	0
	Too soft	2	0	0	1	6	3
	Too narrow	1	0	1	5	4	0
	Too wide	0	0	0	0	0	0
	Too short	0	0	3	4	1	3
	Too long	4	4	0	0	2	0
	Poor Support:						
	Of shoulders	2	3	7	10	8	2
	Of mid-back	3	2	5	6	9	2
	Of small of back	8	5	12	12	10	6
HEADREST	Too firm	6	6	*	*	5	*
	Too soft	0	0	*	*	0	*
	Too narrow	1	0	*	*	0	*
	Too wide	0	0	*	*	0	*
	Too low	0	0	*	*	1	*
	Too high	13	13	*	*	5	*
	Too far forward	7	7	*	*	4	*
	Too far back	6	5	*	*	7	*
ARMRESTS	Too short	7	6	*	*	*	3
	Too long	0	0	*	*	*	0
	Too narrow	7	9	*	*	*	2
	Too wide	0	0	*	*	*	0
	Too close	5	4	*	*	*	2
	Too far apart	1	1	*	*	*	1
	Too low	0	0	*	*	*	0
	Too high	5	2	*	*	*	0

*Indicates not applicable

In the Post-Test Questionnaire, one additional feature asked about was thigh pads. Thigh pads on Seats #1 and #2 were considered by the majority of subjects to be good features. On the other hand, the thigh pad on Seat #4 was considered potentially good only if changes in construction were made. In general, the subjects thought that thigh pads added to comfort, but only if they were of types found on Seats #1 and #2, i.e., separate and quite flexible. (See Figures 17 and 18, pages 65 and 67). The rigid bar-type thigh pad on Seat #4 was considered undesirable (see Figure 20, page 71).

It can also be seen by inspection of Table 6, that 7, 8, and 9 individuals, respectively, felt that headrests would provide more comfort if added to Seats #X, #4, and #6. More subjects, however; 16, 13, and 15 respectively, felt that armrests should be added to Seats #X, #4, and #5. Obviously, subjects considered armrests far more important than headrests.

Final Evaluation of Seat Adjustments and Controls

Preferred Seat Adjustments. As stated earlier, when a subject desired to adjust his seat during a test period, an Experimenter's Questionnaire (Appendix II, page 89) was filled out. The particular adjustment and the exact time at which it was made were recorded. Thus, a record was available of the total amount of time spent in each seat adjustment. The dimensions recorded were: SRP* to floor (height), SRP to footrest**, and the angles of the seat pan and seat back. Table 7 presents this data.

In general, it can be seen that in Seats #1, #2, and #6, which were pilot seats run with footrests, the vertical adjustments most frequently used were between approximately 14" and 18" (SRP to floor). In Seats #4 and #5, which had no footrests, the preferred heights were between 17" and 20". The frequent use of a seat height of 20" on Seat #5 is very likely due to cushion softness which resulted in lowering the SRP by two or three inches when the seat was occupied. It can also be seen that there were dual preferences for seat heights in each seat. In Seat #1 these were $14\frac{1}{2}$" to 16", and $17\frac{1}{2}$" to 18"; in Seat #2, 15" and $16\frac{1}{2}$" to 18"; in Seat #5, 18" and 20" to $20\frac{1}{2}$"; in Seat #6, 15" and 16" to $16\frac{1}{2}$".

The preferred distances between SRP and footrests ranged between $35\frac{1}{2}$" and $41\frac{1}{2}$". Since the footrests were adjustable only in increments of 2", these figures should be taken only as a very rough indication of preferences.

In Seats #1, #2, and #6, which have adjustable pan and back angles (Seat #6 has a fixed seat pan angle with an independently adjustable back), the preferences were obviously for the more upright back angles (100° to 114°). This preference for more upright positions was very likely related to the fact that the subjects spent most of their sitting time studying. The larger back angles were used during shorter periods of relaxation.

---

*SRP - Seat Reference Point. Defined as the midpoint of the intersection of the planes formed by the seat cushion and the back cushion.

**The point of measurement on the footrest is a line drawn on the slope of the footrest, five inches up from the floor.

Table 7

Total Time in Minutes Spent in Various Seat Adjustments

	Seat Height			SRP to Footrest		Seat Angles*		
	Range of Adjustments (inches)	SRP to Floor (inches)	Total Time (mins.)	SRP to Footrest (inches)	Total Time (mins.)	Angles Pan°	Angles Back°	Total Time (mins.)
Seat #1 (16 Subjects)	13½ - 18½	13½	261	35½	2030	1	104	2455
		14	406	37½	1735	3	109	1967
		14½	890	39½	750	5	114	406
		15	0	41½	915	6	119	528
		15½	720	43½	420	7	124	491
		16**	728					
		16½	180					
		17	347					
		17½	820					
		18	660					
		18½	420					
Seat #2 (18 Subjects)	13½ - 20½	13½	560	27½	135	1	104	2608
		14	0	29½	270	3	109	2239
		14½	20	31½	400	5	114	1512
		15	1690	33½	190	6	119	500
		15½	120	35½	630	7	124	0
		16	0	37½	1918			
		16½	798	39½	2116			
		17**	820	41½	700			
		17½	961					
		18	1180					
		18½	0					
		19	610					
Seat #X (18 Subjects)	Fixed at 9"			35½	585	9	109 (fixed)	4532
				37½	1906			
				39½	147			
				41½	1534			
				43½	310			

(continued)

Table 7 -(Continued)

	Seat Height			SRP to Footrest		Seat Angles*		
	Range of Adjustments (inches)	SRP to Floor (inches)	Total Time (mins.)	SRP to Footrest (inches)	Total Time (mins.)	Angles Pan°	Angles Back°	Total Time (mins.)
Seat #4 (16 Subjects)	17¼ - 19¼	17¼	4038			7	102	4743
		18¼**	705			(fixed)		
Seat #5 (17 Subjects)	16½ - 21½	16½	520			2	100	5057
		17	0			(fixed)		
		17½	92					
		18	1035					
		18½	235					
		19**	723					
		19½	150					
		20	1227					
		20½	955					
		21	60					
Seat #6 (17 Subjects)	13 - 20	14½	420	29¼	410	9	100	4228
		15	3730	31¼	0	9	106	1042
		15½	420	33¼	0	9	110	1597
		16	815	35¼	2020	9	115	0
		16½**	1140	37¼	1765	9	119	58
		17	0	39¼	1865	9	123	0
		17½	275	41¼	525	9	127	0
		18	0	43¼	0			
		18½	60	45¼	275			

*Angles are calculated with respect to horizontal.
**Neutral Position.

Adjustability and Controls. In order to ascertain the adequacy of the adjustments provided by each seat, subjects were asked to evaluate each seat in terms of adjustability (see Appendix II, page 92).

Table 8 presents these data. It can be seen that most subjects considered adjustability an important feature. They suggested that Seats #4 and #5 were inadequate because of their fixed pan and back angles. It was also suggested that Seat #4 should have a greater range of vertical adjustment. The explanation for this suggestion seems obvious, because in this seat much discomfort was caused by the bar-type thigh pad and the fact that the seat could not be adjusted lower than $17\frac{1}{4}$", so that many subjects could not avoid excessive pressure on the thighs and in the popliteal area (under the knees). Other suggestions were: (1) The headrests on Seats #1 and #2 should be made adjustable; (2) Some seat back adjustability for the small of the back would improve the comfort of Seat #6.

Table 8

Evaluation of Adjustability of Each Seat

Adjustability	Seat #1 16 Subj.	Seat #2 18 Subj.	Seat #X 18 Subj.	Seat #4 16 Subj.	Seat #5 17 Subj.	Seat #6 17 Subj.
Enough	14	16	1	4	5	14
More Needed			8	10	12	
More Seat Adj. Needed		1	4	4	3	1
More Back Adj. Needed	1		5	8	11	
More Height Adj. Needed			4	6		
Other	1 (Headrest)	1 (Headrest)				1 (Small of Back)

Although somewhat apart from comfort evaluation, it was considered desirable to evaluate the ease of operation of the seat adjustment controls. To do this, the following question was included in the Post-Test Questionnaire (see Appendix II, page 92):

2. Evaluate the ease of manipulation of the seat adjustment controls:

	Just Right	Adequate	Inaccessible	Hard to Reach	Hard to Move	Confusing	Inadequate
Seat pan angle	___	___	___	___	___	___	___
Back angle	___	___	___	___	___	___	___
Height	___	___	___	___	___	___	___
Fore and aft	___	___	___	___	___	___	___
Lateral	___	___	___	___	___	___	___
Swivel	___	___	___	___	___	___	___

Table 9

Frequencies of Comments on Seat Adjustment Controls

		Control Evaluation						
	Adjustment Control	Just Right	Ade-quate	Inac-cessible	Hard to Reach	Hard to Move	Con-fusing	Inade-quate
Seat #1 (16 Subjects)	Pan angle	11	3	0	1	0	0	1
	Back angle	10	5	0	1	0	0	0
	Height	8	4	0	0	2	0	2
	Fore & Aft	10	3	1	2	1	0	0
	Lateral	*	*	*	*	*	*	*
	Swivel	*	*	*	*	*	*	*
Seat #2 (18 Subjects)	Pan angle	15	2	0	0	0	0	1
	Back angle	17	1	0	0	0	0	0
	Height	10	5	0	1	3	0	0
	Fore & Aft	7	6	0	4	1	0	0
	Lateral	8	1	0	1	7	0	3
	Swivel	*	*	*	*	*	*	*
Seat #4 (16 Subjects)	Pan angle	*	*	*	*	*	*	*
	Back angle	*	*	*	*	*	*	*
	Height	0	1	6	11	9	1	1
	Fore & Aft	5	5	0	1	7	0	0
	Lateral	15	0	0	0	0	0	1
	Swivel	10	6	0	0	1	0	0
Seat #5 (17 Subjects)	Pan angle	*	*	*	*	*	*	*
	Back angle	*	*	*	*	*	*	*
	Height	2	6	0	0	9	0	1
	Fore & Aft	3	7	0	5	5	0	1
	Lateral	*	*	*	*	*	*	*
	Swivel	4	6	0	0	6	2	1
Seat #6 (17 Subjects)	Pan angle	11	3	0	2	0	0	1
	Back angle	9	4	0	2	0	0	2
	Height	12	3	0	2	2	0	0
	Fore & Aft	12	4	0	1	0	0	0
	Lateral	*	*	*	*	*	*	*
	Swivel	*	*	*	*	*	*	*

* means not applicable

Table 9 summarizes evaluation of the seat adjustment controls. On Seat #2, subjects found lateral adjustments difficult to make. On Seat #4, subjects found the height adjustment to be inaccessible, hard to reach, or hard to move. They also found fore and aft adjustments difficult to make. On Seat #5, subjects found the height adjustment difficult to make while seated. Some subjects also found the fore and aft adjustment control hard to reach and the adjustments difficult to make. Several found the seat difficult to swivel. There were relatively few complaints about Seats #1 and #6. More complete and detailed analyses of these criticisms will be presented in subsequent reports evaluating the seats individually.

ANTHROPOMETRICS AND SEAT PART EVALUATIONS

The data were analyzed to determine whether there were any correlations between complaints concerning seat dimensions and categories of subjects determined by body measurements, but no consistent correlations were revealed. Noting that the seats are all based on HIAD recommendations (18), this lack of correlation substantiates a premise of the present seating study. The premise (see page 10) states something we all recognize - that adequacy of seat dimensions does not necessarily assure comfort, but that many other factors are involved. Since dimensions in all the seats are based on HIAD, it is not to be expected that adequacy of size characteristics would vary grossly from seat to seat. HIAD size recommendations reflect considered judgments by many designers influenced by feed-back from operating squadrons with long experience. HIAD recommendations also reflect a series of seating studies, such as that of Randall, Damon, Benton and Patt (15), which were specifically dedicated to defining seat dimensions to accommodate a wide range of sizes in the Air Force population. The absence of correlations between body dimensions and complaints in the present study can be regarded as evidence that these studies were successful.

If the matter be pursued further, however, it is noted that dimensions of parts do vary considerably from seat to seat (e.g., the seat cushion in Seat #6 is 19" in length while in Seat #5 the cushion is only 13" in length). Dimensions of the seats are not strictly according to HIAD recommendations, but are based on HIAD recommendations as modified by compromises in particular seat specifications. Furthermore, there are suggestions in the data from the present seating study that some seat parts are best fitted by size to serve the larger percentiles of the Air Force population while others best serve the smaller ones. Some complaints made by subjects, (e.g., that the headrests on Seats #1, #2 and #5 are too high) would be expected to correlate with subjects' dimensions. However, these complaints actually were scattered throughout the whole range of body sizes.

The absence of correlations between size categories of subjects and complaints concerning seat dimensions also relates to the size of the study sample. Taken as a whole, the sample is sufficient to give consistent differentiations of the seats by several methods, and there is statistical evidence that 12 subjects gave the same results as 18 (see Table 1, page 16). However, dividing a sample of 12 or 18 subjects into sub-categories by body sizes results in cells containing too few numbers for statistical treatment. Stated in reasoned terms, there are now too few subjects in each category to balance for individual differences in tolerance for discomfort; or, it might be said that a "tough-bottomed" small man has more in common with a "tough-bottomed" large man than he has with small men in general.

The premise of the anthropometric approach to seating studies, as aptly stated by Hooton in his railroad seat study (7), is that comfort cannot be obtained without a sound knowledge of bodily dimensions. It would be rewarding to bridge the gap between this approach and the comfort measurement approach by showing correlations between measured discomfort and body sizes. But increasing the numbers of subjects in a comparative study to permit subdividing the sample into categories by body sizes - so that each category would support statistical analyses - would be prohibitive in time expenditures when each test must run several hours. Even the development of shorter testing methods might not solve the problem, since discomfort caused by specific seat parts may only become evident after sitting periods of considerable lengths. However, if extended seating periods are not required, correlations between body dimensions and measured discomfort must still await the development of short, standardized comfort tests.

SPONTANEOUS COMMENTS

In one of the last sections of the Post-Test Questionnaire, (Appendix II, page 92), space was provided in which the subject could write any comments he wished to make. This information, although valuable for the evaluation of the individual seats, has little application to the comparative approach. These comments therefore, are not included here, but will be presented in subsequent reports evaluating individual seats.

SUMMARY AND DISCUSSION

Comfort is a qualitative experience that admittedly is difficult to assess. Not only are the subjective feeling-states of an individual difficult to examine, but the term "comfort" itself lacks rigorous definition. In part the difficulty stems from the fact that too few scientists have attempted to examine the factors that are involved in this unique experience. Although the concept of comfort and the qualities of experience involved in it are not well understood, the results of this study present ample evidence that carefully planned evaluative techniques can be applied with confidence where comfort needs to be assessed. Utilizing voluntary sitting times, plus a multi-item questionnaire employing a battery of approaches - including rating scales, comfort predictability, and hourly comfort evaluations - the present study has produced results that show empirically (through relatively consistent agreement among the several comfort measuring techniques) that a number of aircraft seats can be compared in terms of their "comfort-yielding" characteristics, and that any of the seats can be examined individually by these procedures.

Table 10 and Figure 16 outline the various methods used to rank and evaluate the aircraft seats examined in this study.

As can be seen, a good degree of consistency exists between the several methods. However, from a practical viewpoint - comparing these methods as to efficiency and ease of application to seat evaluation - there are differences which merit consideration.

In the present study, the maximum sitting time was set at 7 hours. While this fixing of test duration was necessary to insure the availability of subjects and monitoring personnel, it imposed certain limitations on the use of voluntary sitting time as an index of seat evaluation. With the time limitation, the method served adequately for the less comfortable seats, but it was less useful for the more comfortable seats in which high proportions of the subjects sat the maximum length of time. To take the extreme case, ten of the 17 subjects remained in Seat #6 for the full 7 hours. Presumably, a good number of these subjects could have sat considerably longer. The end result was that, although more subjects remained in Seat #6 for the maximum length of time, and although average length of sitting time was definitely longer in Seat #6 than in any other seat, it was not possible to separate Seat #6 statistically from the other pilot seats. This likely was because the duration of the test was limited. The same problem would arise in any test of seating where voluntary sitting time is used as a measure of seating discomfort. Therefore, to use sitting time to greatest advantage, it would be necessary to allow the subjects to sit indefinitely until each reached maximum tolerance for each seat. This procedure, however, would become lengthy and expensive, and scheduling difficulties would be extreme. Since the greatest attrition, in the present experiment, occurred between the fourth and fifth hours, it is suggested that 4 or 5 hours would be adequate when fixed sitting periods are desired for testing purposes.

In the present study, the percentages of subjects lasting to the 8th questionnaire (i.e., between 6 and 7 hours) can also be used to rank the seats. This index is possibly more useful than mean sitting times because it utilizes

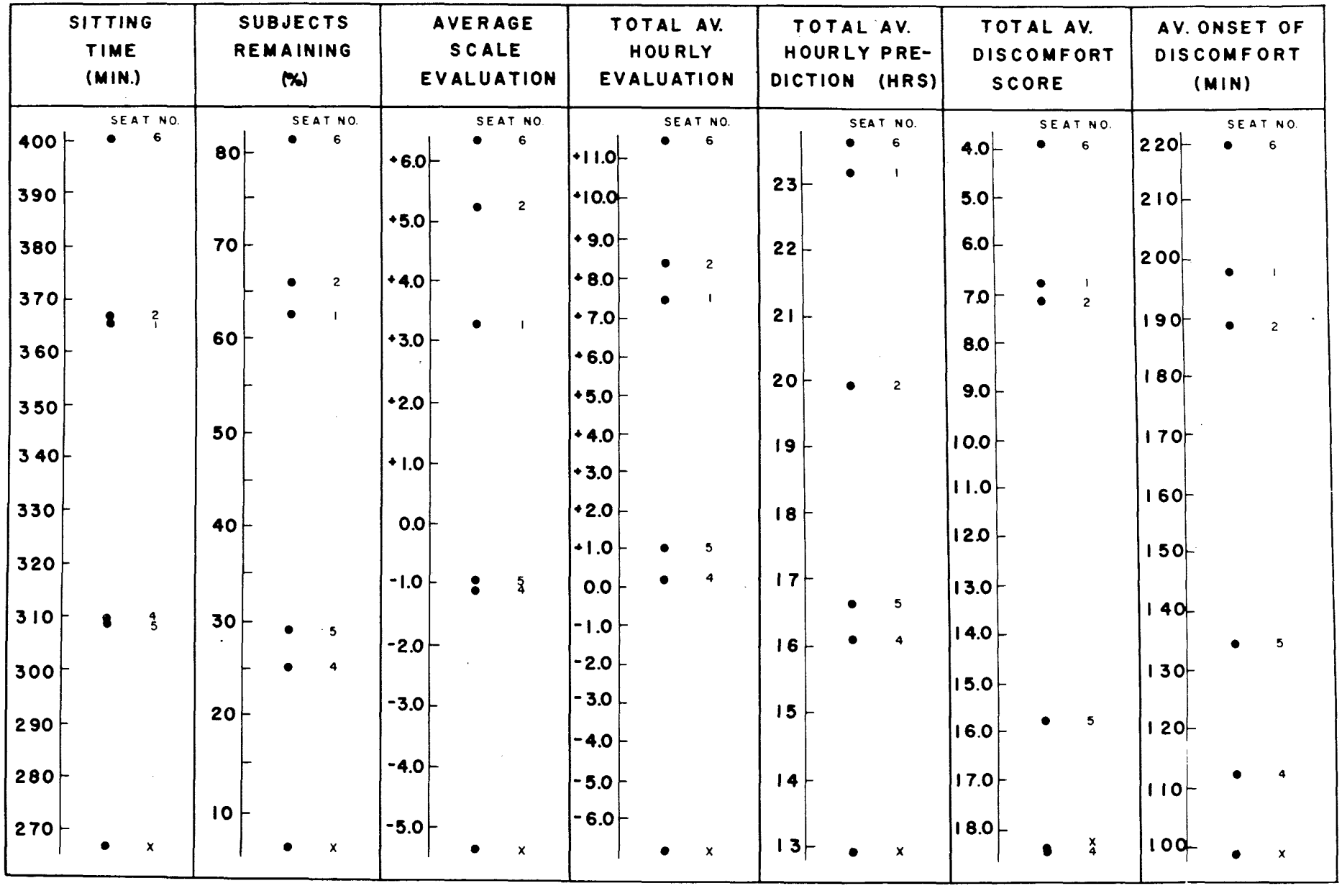

Figure 16

Comparison of Seat Ranking Methods

those sitting periods which would have continued, perhaps for protracted periods, if there had been no limitation on sitting time. However, again, the procedure is lengthy and rather impractical for routine use.

Table 10

Summary of Results of Methods Used to Rank Seats

Seat No.	Sitting Time (Min.) a.	Subjects Remaining (%) b.	Average Scale Evaluation c.	Total Av. Hourly Evaluation d.	Total Av. Hourly Prediction (Hours) e.	Total Av. Discomfort Score f.	Average Onset of Discomfort (Min.) g.
1.	365.9	62.5	+ 3.27	+ 7.4	23.2	6.7	198.0
2.	368.3	66.6	+ 5.24	+ 8.4	19.9	7.1	189.2
X.	267.1	5.5	- 5.29	- 6.8	12.9	18.3	99.1
4.	309.9	25.0	- 1.11	+ 0.3	16.1	18.4	112.6
5.	308.2	29.4	- 0.97	+ 1.0	16.6	15.7	134.5
6.	400.4	82.4	+ 6.59	+11.5	23.6	3.9	220.0

a. See Table 14, Appendix III, page 96.
b. Percent of Subjects remaining in seats over 6 hours. (See Figure 4, page 22.)
c. See Table 16, Appendix IV, page 99.
d. See Table 17, Appendix V, page 100.
e. See Table 18, Appendix VI, page 101.
f. See Table 26, Appendix VII, page 109.
g. See Table 27, Appendix VII, page 110.

A comfort rating scale proved to be a quick and efficient ranking method. Since this test was administered only after the end of the sitting period, it is not known if there would have been differences in the ratings had the subjects been required to mark a scale early in the sitting period.

The data derived from hourly evaluations of the degree of comfort provided by the seat at the moment, reflect indirect measures of the momentary state of comfort of the subject as it relates to his opinion of the seat. In the present experiment, ranking of the seats remained quite consistent from the first questionnaire through the fifth, suggesting that the method had good stability. This procedure would, therefore, be useful in seating tests of 4 to 5 hours duration.

When subjects were asked hourly to predict how much longer they would be able to remain in the seat, their predictions implicitly involved estimations of how comfortable the seat was going to remain. The subjects were able, from the first questionnaire on, to make accurate predictions about four of the seats. However, their initial predictions about two of the seats were revised downward after about one hour. The method was thus able to point out seats which at first seemed as though they were going to be more comfortable than subsequent experience

revealed them to be. For most purposes, this method can probably be useful in short term seating tests.

Totals of the average hourly discomfort scores for all body regions combined (total average discomfort) were used in ranking the seats. Although most of the other methods ranked Seat #4 very close to Seat #5, this method ranked #4 considerably below #5 and, in fact, very close to Seat #X. It is very likely that this method ranks Seat #4 very low because it is sensitive to the discomfort afforded by individual seat parts, and thus reflects the inordinate amount of thigh discomfort afforded by Seat #4. Other methods were insensitive to this specific discomfort possibly because, either the subjects thought of this thigh discomfort as resulting from a special seat feature and thus apart from general discomfort, or thigh discomfort was considered to be much less important than discomfort in other body regions. The method of totalling average discomfort scores is useful in seat evaluation since it can be employed in tests of either short or long durations.

The results from using average time of onset of discomfort combined for all body regions were quite similar to those determined by using totals of average discomfort scores. Thus, the sooner discomfort began, the greater discomfort tended to be. This procedure, if assigned primary importance in a testing program, would permit termination of a sitting period when discomfort begins; and time of onset of discomfort (or average test duration) could be used to rank the seats. Other aspects of discomfort are peak and duration. Information on these, along with data about time of onset, could be extremely valuable for determining the pattern and absolute magnitude of discomfort. In order to obtain such data, however, it would be necessary to utilize extremely prolonged sitting periods.

Data derived from the study of discomfort in particular body regions revealed that the greatest amounts of discomfort were experienced in the back and buttocks and that these conditions influenced seat evaluations. Lack of seat adjustability contributed to back discomfort as well as did the particular magnitudes of back angles present in seats having fixed backs. Improper seat cushioning also contributed to back discomfort. Discomfort in the buttocks was, of course, highly influenced by the cushioning. Moreover, it was revealed that cushions that are too soft may be very nearly as detrimental to comfort as no cushions at all.

Second in importance was discomfort in the neck and thighs. Although headrests seemed to have little to do with neck comfort, the presence of armrests and/or seat back adjustability were important factors.

Discomfort in thighs was caused mainly by poorly designed thigh pads and excessively short seat cushions.

Least important was discomfort in the shoulders and lower legs. Discomfort in the shoulders was influenced mainly by adjustability of the seats, while discomfort in the lower legs was associated with factors producing thigh discomfort.

The types of discomfort developed during protracted sitting periods are poorly understood. An exploratory approach was therefore used in an attempt to gain qualitative information about discomfort in each body region. Using certain initial assumptions, it was possible to tentatively suggest that superficial

discomfort (in the skin and underlying tissues) was most frequent in areas coming in contact with the seat. Deeper-lying discomfort (in the muscles and joints) was most frequently associated with body parts concerned with postural support. Types of discomfort commonly associated with interference of blood circulation were least frequent. These considerations, although speculative, suggest the need for further research. It is obvious that a better knowledge of the types and degrees of discomfort associated with each body region would be invaluable for more adequately defining the roles that the various body regions play in the development of seating discomfort.

In the present study, subjects were asked to evaluate certain parts of each seat every hour. A similar series of questions was presented in the final Post-Test Questionnaire. Comparison of data from these two series of questions revealed essentially no differences. This finding questions the necessity of hourly presentations of the questionnaires. However, while a single presentation at the end of the sitting period is time saving and easier to administer, hourly presentations do have some usefulness. This usefulness, rather than for obtaining data, lies in keeping the awareness of subjects at such a level that attention is continuously (or periodically) focused on the analysis of characteristics of the seat parts and on the subject's comfort state.

In conclusion, it can be said that the several methods described above represent an exploratory approach to the subjective study of seating comfort. No one of the methods alone can be considered adequate for testing seats. Instead, at least two or three of these methods must be used simultaneously in any seat testing procedure. Selection of the methods should be based upon the type of information desired and upon the ability of each method to serve as a check against the others.

At present, little is known about the subjective state of discomfort. The terminology used to describe discomfort is poorly understood and the degree to which certain subjective sensations contribute to total discomfort is unknown. It is obvious that an individual's concept of discomfort is ultimately associated with psychological factors. The key to many problems in comfort measurement lies in the study of individual differences in tolerance for discomfort. Any information about these several relevancies would be invaluable in comprehension of discomfort and in the development of more adequate comfort-measuring techniques.

Although psycho-physiological approaches to seat comfort testing are ultimately desirable, they have little chance of success until adequate subjective measures are available against which they can be validated.

While it is not the purpose of this report to provide the final answers to the problem of seat comfort evaluation, it is hoped that the questions it raises will serve as a stimulus for further research in the field of human comfort.

CONCLUSIONS

1. Sitting Time:

(1.1) The use of average voluntary sitting time as a measure of seat preference was successful and statistical separation of the seats was demonstrated. However, because of the great amount of time involved, voluntary sitting time is not recommended for use as a routine procedure. (See pages 15-19.)

(1.2) Since most of the subjects voluntarily left the seats after four to five hours, it is suggested that this length of time is adequate for most seat testing purposes. (See pages 21-23.)

(1.3) Statistical treatment of sitting-time data obtained from twelve subjects gave essentially the same results as those obtained with eighteen subjects. This suggests that, in a properly designed experiment, the smaller number of subjects is adequate. (See page 16.)

2. Rating Scales:

(2.1) The use of rating scales to determine seat preference was a short and efficient means of assigning relative "scores" to seats. (See pages 19-21.)

3. Hourly Evaluation of Comfort:

(3.1) The hourly evaluation of the degree of comfort provided by a seat was a useful procedure both for ranking the seats and for following progressive changes of opinion concerning comfort of the seats. (See pages 23-25.)

(3.2) Hourly predictions by a subject of how much longer he could sit in a particular seat were useful for ranking the seats. The method also was able to single out seats which at first seemed more comfortable than they actually became later. (See pages 26-28.)

4. Body Regions in Seating Discomfort:

(4.1) Average hourly discomfort scores obtained for each body region revealed that the body regions, in order of decreasing importance in seating discomfort were: the buttocks, the back, the thighs, the neck, the shoulders, and the lower legs. (See pages 28 and 36.)

(4.2) Discomfort in the buttocks and back most directly influenced the ranking of the seats. (See pages 28, 31-34, and 36.)

(4.3) Discomfort in the thighs was of little importance in all except one of the seats, and could not be used in ranking the seats. (See pages 28, and 34-36.)

(4.4) Discomfort in the neck was negligible and had little influence on the ranking of seats. (See pages 28, 30, and 36.)

(4.5) Discomfort in the shoulders and in the lower legs was negligible and had little influence on the ranking of seats. (See pages 28, 30-31; 36-37.)

5. "Total Discomfort" Scores:

(5.1) Total discomfort scores (gross indices of discomfort derived by summing average hourly discomfort scores obtained for specific portions of the body) were useful in ranking the seats, and could be used profitably in tests of the order of four to five hours in duration. (See pages 39-40.)

6. Onset of Discomfort:

(6.1) The average time of onset of discomfort was a useful means for ranking the seats. Since the time of onset is closely related to the total amount of discomfort experienced in the seat, onset may be used as an indirect index, or predictor, of total discomfort. (See pages 40 and 41.)

7. Body Discomfort and Seat Design:

(7.1) Inadequate cushioning was largely responsible for buttocks discomfort and was shown to be nearly as detrimental to comfort as was complete lack of cushioning. (See pages 31, 33-34; 44-48.)

(7.2) Lack of adjustability in the seat back was a partial cause of back discomfort. (See pages 31-32; 44-48.)

(7.3) Discomfort in the thighs was of little importance except in one seat where a bar-type thigh pad caused excessive discomfort. (See pages 34-36; 44-48.)

(7.4) Short seat cushions also contributed to thigh discomfort. (See pages 34-36; 44-48.)

(7.5) Discomfort in the lower legs was negligible but was influenced by the same factors which caused thigh discomfort. (See pages 36; 44-48.)

(7.6) Presence or absence of a headrest had little effect upon neck comfort, but seat back adjustability and armrests tended to alleviate neck discomfort. (See pages 28; 44-48.)

(7.7) Shoulder discomfort had a negligible influence on the ranking of seats, but comfort of the shoulders was adversely affected by lack of seat back adjustability. (See pages 30-31; 36; 44-48.)

8. Summaries of Seat Evaluations:

The following are summaries of data obtained for each seat. Suggestions listed below are taken directly from appraisals made by the subjects.* Seats are listed in decreasing order according to subject's preference.

---

*Suggestions include only those made by five or more subjects.

Seat #6 C-118 Pilot Seat (Aerotherm)

Average length of voluntary sitting time		400.4 minutes
Average time of onset of discomfort		220.0 minutes
Total discomfort score		3.9
Comfort scale rating		+ 6.59
Most used vertical adjustments (SRP to floor)		15"; also 16" to 16½"
Most used seat angle adjustments (with respect to horizontal)	(Seat pan fixed at 9°)	Back 100° & 106°

Suggestions: Headrest should be added.

Seat #2 C-124A Pilot Seat (Gravity Load) (Weber)

Average length of voluntary sitting time		368.3 minutes
Average time of onset of discomfort		189.2 minutes
Total discomfort score		7.1
Comfort scale rating		+ 5.24
Most used vertical adjustments (SRP to floor)		15"; also 16½" to 18"
Most used seat angle adjustments (with respect to horizontal)	Seat Pan 1° - 3°	Back 104° & 109°

Suggestions: Seat cushion is too firm.
Seat back is too firm.
Seat back offers poor support for small of back.
Headrest is too high (29").
Armrests are too short (15") and narrow (3").
Lateral adjustment is difficult to make.

Seat #1 C-97A and KC-97E Pilot Seat (Long Range) (Weber)

Average length of voluntary sitting time		365.9 minutes
Average time of onset of discomfort		198.0 minutes
Total discomfort score		6.7
Comfort scale rating		+ 3.27
Most used vertical adjustments (SRP to floor)		14½" to 16"; also 17½"
Most used seat angle adjustments (with respect to horizontal)	Seat Pan 1° - 3°	Back 104° & 109°

Suggestions: Seat cushion is too soft.
Seat cushion is too short without thigh pads (14").
Seat back offers poor support for small of back.
Headrest is too high (29½").
Armrests are too short (14½"); too narrow (3½");
too high (9" from seat), and too close together (18½").

Seat #5 C-124 Crew Seat (Weber)

Average length of voluntary sitting time	308.2 minutes
Average time of onset of discomfort	134.5 minutes
Total discomfort score	15.7
Comfort scale rating	- 0.97
Most used vertical adjustments (SRP to floor)	18"; also 20" to 20½"

Suggestions:
Seat cushion is too soft and too short (13-3/4")
Seat back is too soft and gives poor support to shoulders, middle of back, and small of back.
Headrest is too high (27").
Armrests should be added.
Adjustable back is needed.
Height adjustment is difficult to make.
Fore and aft adjustment is hard to reach, and difficult to move.
Swivel adjustment is difficult to make.

Seat #4 C-124A Crew Seat (Hardman Model 605)

Average length of voluntary sitting time	309.9 minutes
Average time of onset of discomfort	112.6 minutes
Total discomfort score	18.4
Comfort scale rating	- 1.11
Most used vertical adjustments (SRP to floor)	17¼"

Suggestions:
Seat cushion is too short without thigh pads, (16"); too narrow (16"), and too soft.
Seat back is too narrow (tapering) and offers poor support to shoulders, middle of back, and small of back.
Thigh pad is uncomfortable.
Headrest should be added.
Armrests should be added.
More range in vertical adjustment is needed.
Back adjustment is needed.
Vertical adjustment is inaccessable or hard to reach, and hard to move.
Fore and aft adjustment is difficult to make.

Control Seat (Plywood)

Average length of voluntary sitting time	267.1 minutes
Average time of onset of discomfort	99.1 minutes
Total discomfort score	18.3
Comfort scale rating	- 5.29

LEGEND
Seat No. 1 Figure 17

GENERAL DESCRIPTION

Aircraft	C-97A & KC-97E
Crew Station	Pilot
Manufacturer	Weber
Remarks	Long Range

DIMENSIONS

Seat Pan	
Cushion - L x W x D	14" x 15½" x 5"
Thigh pads - L x W x D	3" x 6" x 2"
Over-all length - Cushion + Thigh Pad	17"
Remarks	2 thigh pads, 5¼" separation
Armrests	
Cushion - L x W x D	14½" x 3" x 1½" (irregular shape)
Inside distance between	18½"
Height of top surface from surface of seat cushion	9"
Moveable or fixed	Moveable
Remarks	Contoured, foam rubber
Seat Back	
Cushion - L x W x D	24" x 16" x 5"
Headrest - L x W x D	5" radius, semi-circular
Distance - SRP to center of headrest	29½"
Remarks	Headrest, convex, tapered
Maximum envelope - based on full ranges of adjustments - L x W x H	14¼" x 24" x 50"

ADJUSTMENTS

Fore & Aft - range from neutral; increment	± 2½", ½"
Vertical - neutral SRP; (range); increment	16"; (13½" - 18½"); ½"
Seat Pan Angles - relative to horizontal	1° 3° 5° 6° 7°
Seat Back Angles - relative to horizontal	104° 109° 114° 119° 124°
Included angle	103° 106° 109° 113° 117°
Swivel	None
Lateral	None
Remarks	Seat pan angle changes with back angle adjustment in above combinations.

UPHOLSTERY

Covering	Canvas, green
Filling	Semi-perforated, foam rubber

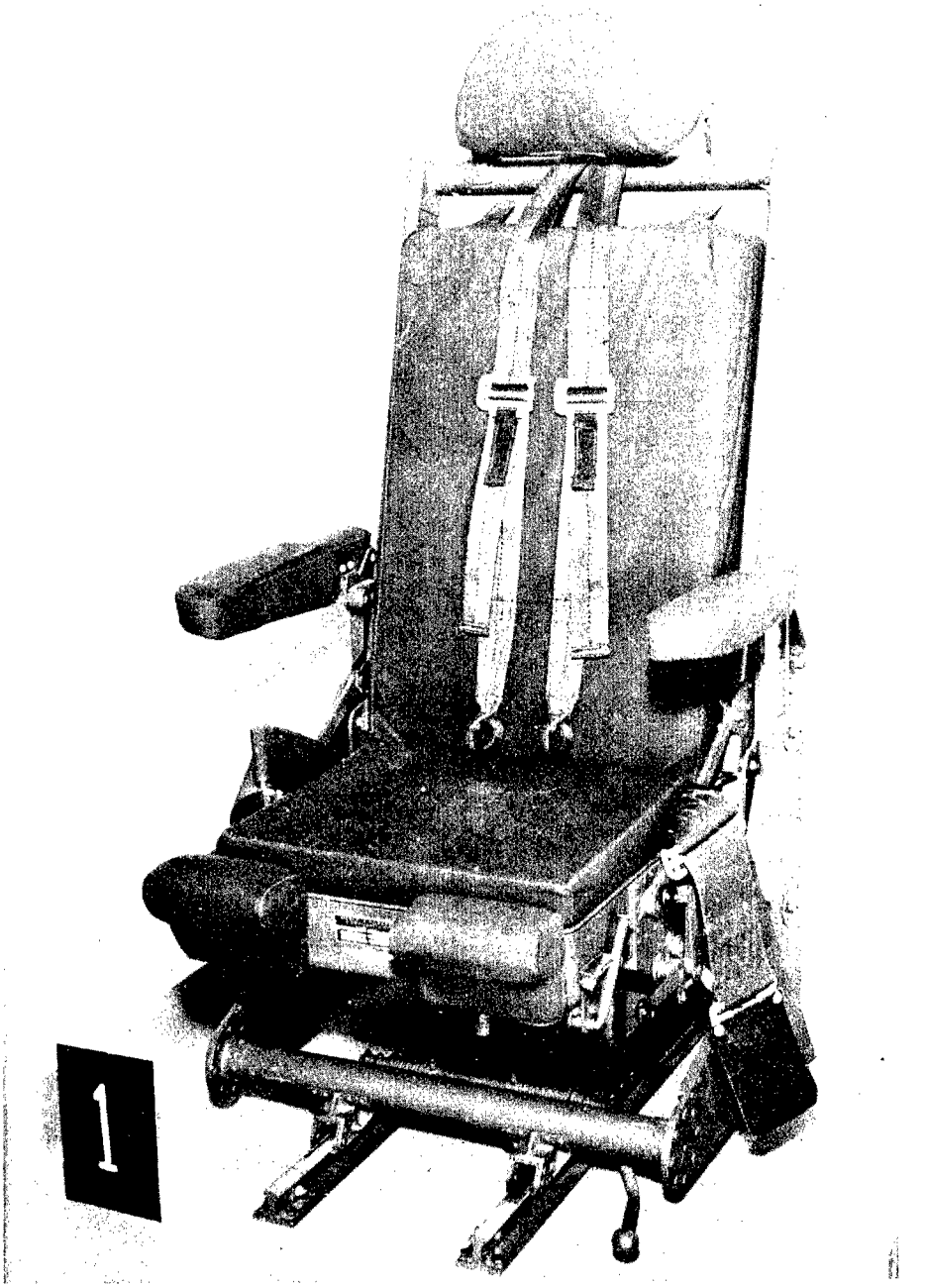

Figure 17

Seat No. 1 C-97A & KC-97E Pilot Seat (Long Range) (Weber)

LEGEND
Seat No. 2 Figure 18

GENERAL DESCRIPTION

Aircraft	C-12L4A
Crew Station	Pilot
Manufacturer	Weber
Remarks	Gravity Load

DIMENSIONS

Seat Pan	
Cushion - L x W x D	14½" x 16" x 5"
Thigh Pads - L x W x D	3" x 5-3/4" x 2"
Over-all length- Cushion + Thigh Pad	18½"
Remarks	2 thigh pads, 5¼" separation
Armrests	
Cushion - L x W x D	15" x 3" x 1½"
Inside distance between	18"
Height of top surface from surface of seat cushion	7½"
Moveable or fixed	Moveable
Seat Back	
Cushion - L x W x D	24½" x 16" x 5"
Headrest - L x W x D	5" radius, semi-circular
Distance - SRP to center of headrest	29"
Remarks	Headrest, convex, tapered
Maximum envelope - based on full ranges of adjustments - L x W x H	51½" x 28" x 51½"

ADJUSTMENTS

Fore & Aft - range from neutral; increment	± 3", ½"; 7¼" (rearward exit range)
Vertical - neutral SRP; (range); increment	17"; (13½" - 20½"); ½"
Seat pan angles - relative to horizontal	1° 3° 5° 6° 7°
Seat back angles - relative to horizontal	104° 109° 114° 119° 124°
Included angle	103° 106° 109° 113° 117°
Swivel	None
Lateral	To right only - 3-3/4" - 1 adjustment
Remarks	Seat pan angle changes with back angle in above combinations

UPHOLSTERY

Covering	Leather, green
Filling	Hair composition in back; coil springs in seat cushion.

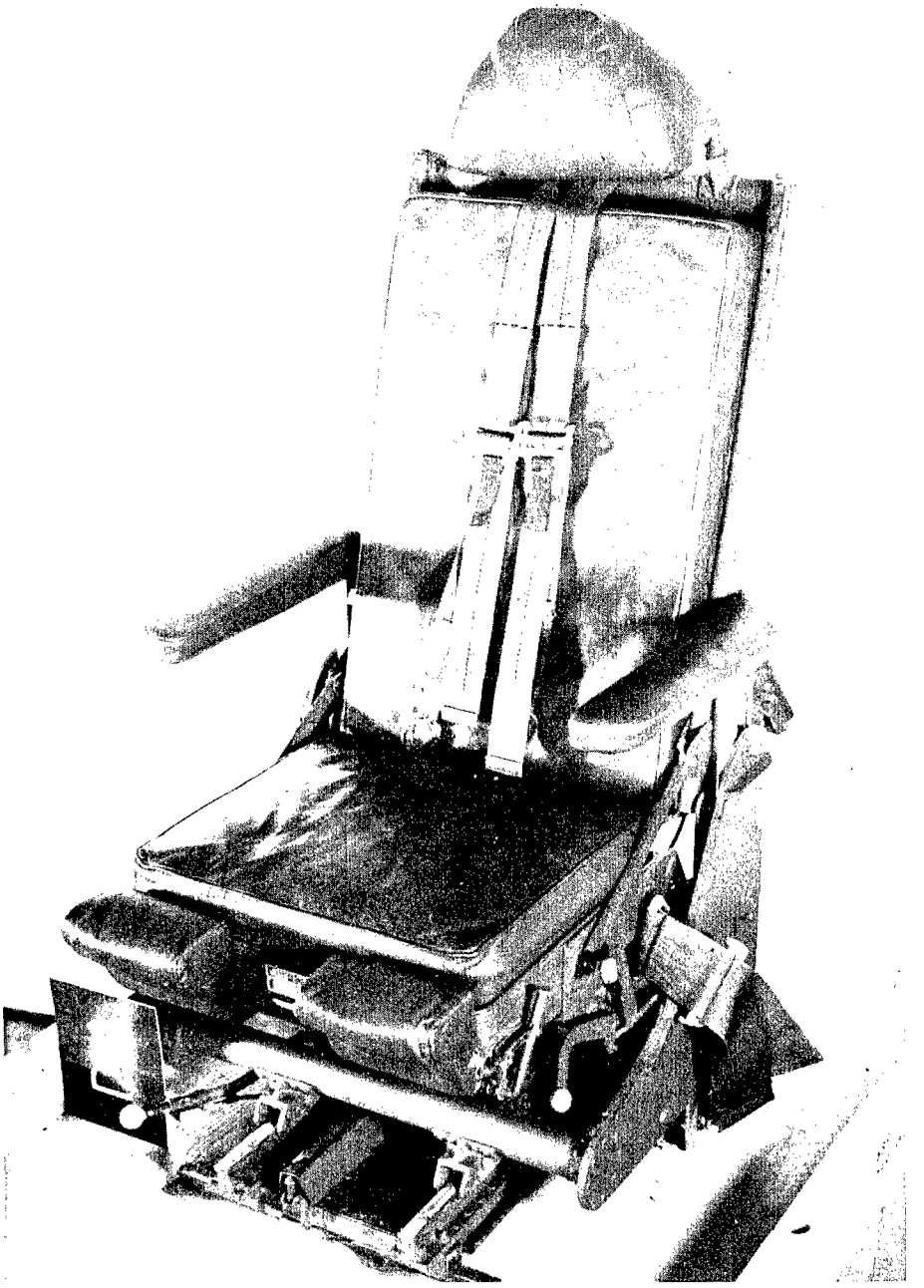

Figure 18

Seat No. 2 C-12L4A Pilot Seat (Gravity Load) (Weber)

LEGEND
Seat No. X Figure 19

GENERAL DESCRIPTION

Control seat; wood, no upholstery

DIMENSIONS

Seat Pan	
Cushion - L x W x D	No cushion, flat pan 15" x 16"
Thigh pads - L x W x D	None
Remarks	None
Armrests	None
Seat Back	
Cushion - L x W x D	No cushion, flat back, 25" x 16"
Headrest - L X W x D	None
Maximum envelope - L x W x H	23¼" x 16" x 23¼"

ADJUSTMENTS

Fore & Aft - range from neutral; increment	None
Vertical - neutral SRP, (range); increment	None
Seat pan angles - relative to horizontal	9° fixed
Seat back angles - relative to horizontal	109° fixed
Included angle	100° fixed
Swivel	None
Lateral	None
Remarks	None

UPHOLSTERY

Covering	None
Filling	None
Remarks	Wood Seat

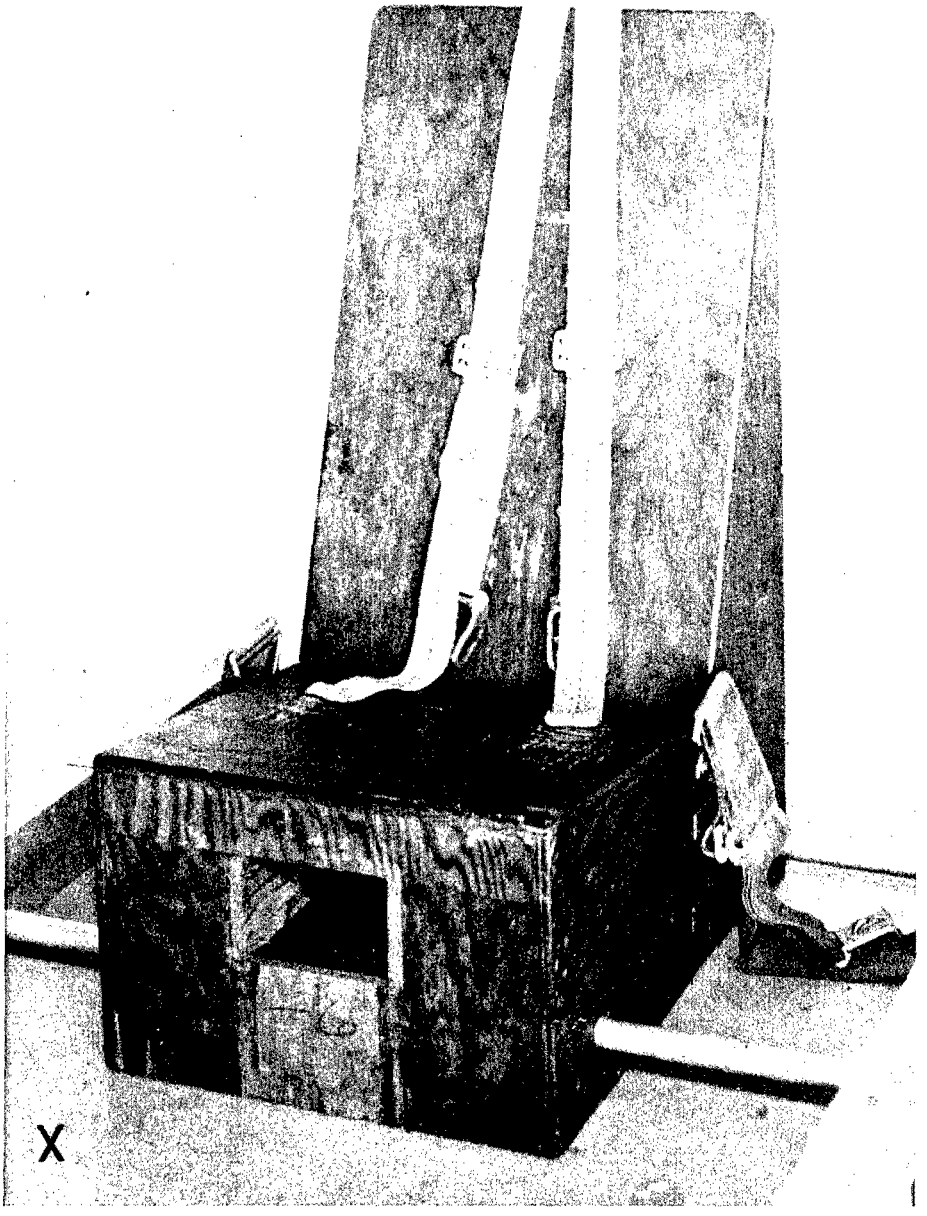

Figure 19

Seat No. X Control Seat

LEGEND
Seat No. 4 Figure 20

GENERAL DESCRIPTION

Aircraft	C-124A
Crew Station	Crew
Manufacturer	Hardman, Model 605

DIMENSIONS

Seat Pan	
Cushion - L x W x D	16"* x 16" x 5½" to 14½"**
Thigh pads - L x W x D	2½" x 15" x 2"
Overall length - Cushion + Thigh pad	19"
Remarks	*Back cushion overlaps seat cushion 2", reducing contact area. **Cushion tapers front to back; single, bar-type thigh pad.
Armrests	None
Seat Back	
Cushion - L x W x D	24" x 16" to 11"* x 8"
Headrest - L x W x D	None
Remarks	*Cushion tapers from mid-point of height to top.
Maximum envelope - based on full range of adjustments - L x W x H	35½" x 35" x 41-3/4"

ADJUSTMENTS

Fore & Aft - range from neutral; increment	± 1½"; 1½"
Vertical - neutral SRP; (range); increment	18¼"; (17¼" - 19¼"); 1"
Seat pan angles - relative to horizontal	7° fixed
Seat back angle - relative to horizontal	102° fixed
Included angle	95° fixed
Swivel; increment	360° swivel; 45°
Lateral	None
Remarks	None

UPHOLSTERY

Covering	Leather, green
Filling	Coil springs

Figure 20

Seat No. 4 C-124A Crew Seat (Hardman, Model 605)

LEGEND
Seat No. 5 Figure 21

GENERAL DESCRIPTION

Aircraft	C-124
Crew Station	Crew
Manufacturer	Weber

DIMENSIONS

Seat Pan	
Cushion - L x W x D	13-3/4" x 16" x 7½"
Thigh pads - L x W x D	None
Remarks	None
Armrests	None
Seat Back	
Cushion - L x W x D	25" x 16" x 3" to 5" to 3"*
Headrest - L x W x D	5"** x 10½" x 8"
Distance SRP to center of headrest	27"
Remarks	*Back of cushion contoured to fit seat back, tapered **Tapered, curved
Maximum envelope - based on full range of adjustments - L x W x H	32½" x 29" x 51"

ADJUSTMENTS

Fore & Aft - range from neutral; increment	± 3"; ½"
Vertical - neutral SRP; (range); increment	19"; (16½" - 21½"); ½"
Seat pan angles - relative to horizontal	2° fixed
Seat back angles - relative to horizontal	100° fixed
Included angle	98° fixed
Swivel; increment	180° swivel; 45°
Lateral	None
Remarks	Swivel adjustment from full aft position only; to right only

UPHOLSTERY

Covering	Canvas, green
Filling	Seat cushion - foam rubber Seat back - layers of fiber glass composition Headrest - foam rubber

Figure 21

Seat No. 5 C-124 Crew Seat (Weber)

LEGEND
Seat No. 6 Figure 22

GENERAL DESCRIPTION

Aircraft	C-118
Crew Station	Pilot
Manufacturer	Aerotherm

DIMENSIONS

Seat Pan	
Cushion - L x W x D	19" x 20" x 4¼" to 3¼"*
Thigh pads - L x W x D	None
Remarks	*Tapered, contoured in all dimensions.
Armrests	
Cushion - L x W x D	Left 13½" x 4-3/4" x 2" Right 10" x 3-3/4" x 2"
Inside distance between	17½"
Height of top surface from surface of seat cushion	8"
Moveable or fixed	Moveable with seat back
Remarks	Armrests differ in shape and dimension.
Seat Back	
Cushion - L x W x D	23" x 20" x varies from 2" to 6"
Headrest - L x W x D	None
Remarks	*Side curved; all surfaces contoured
Maximum envelope - based on full range of adjustments - L x W x H	41" x 26" x 45½"

ADJUSTMENTS

Fore and aft - range from neutral; increment	± 3½"; 1"
Vertical - neutral SRP; (range); increment	16½"; (13" - 20"); ½"
Seat pan angle - relative to horizontal	9° fixed
Seat back angles - relative to horizontal	100° 106° 110° 115° 119° 123° 127°
Included angle	91° 97° 101° 106° 110° 114° 118°
Swivel	None
Lateral	None

UPHOLSTERY

Covering	Leather, red
Filling	Foam rubber

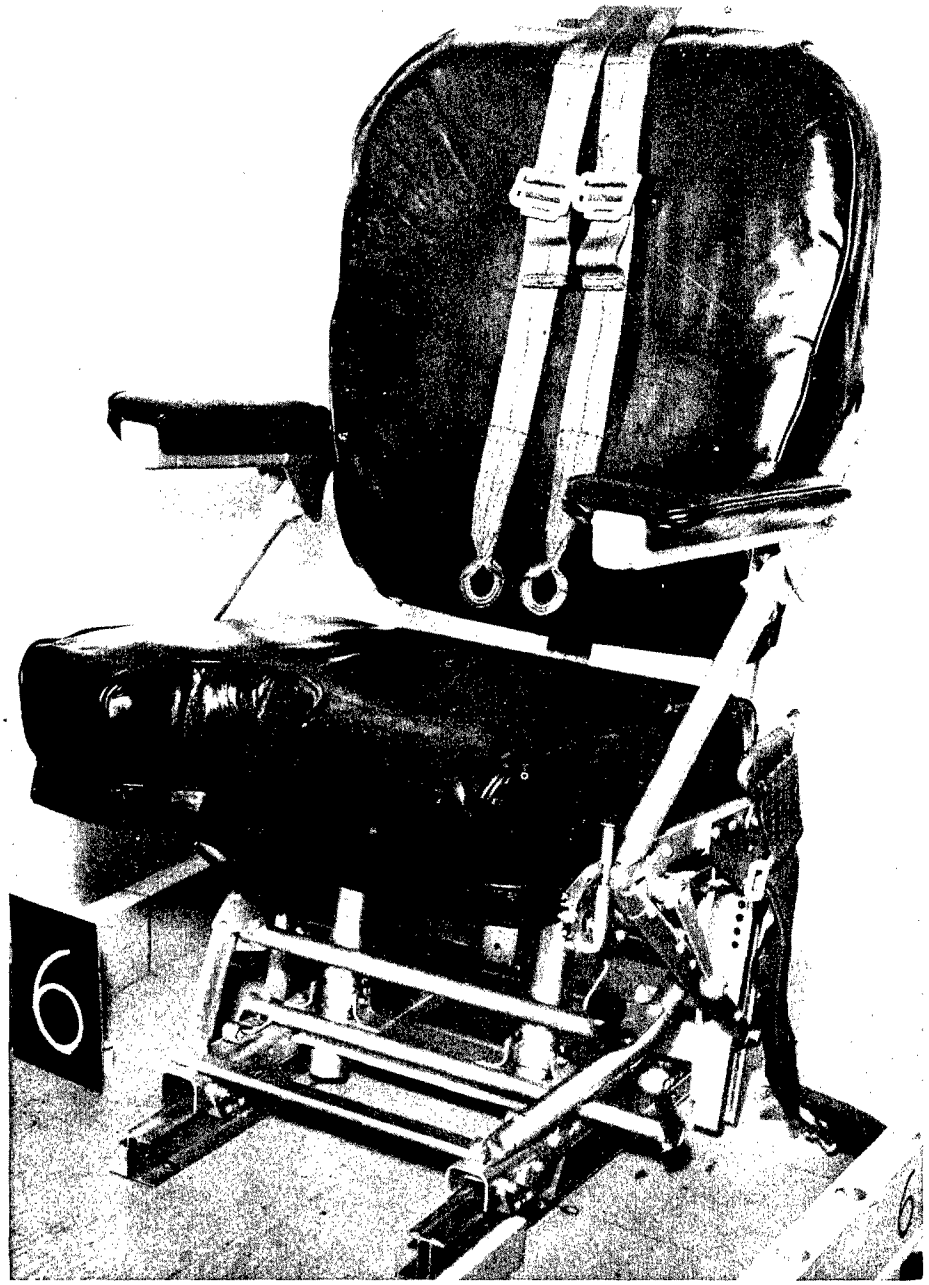

Figure 22

Seat No. 6 C-118 Pilot Seat (Aerotherm)

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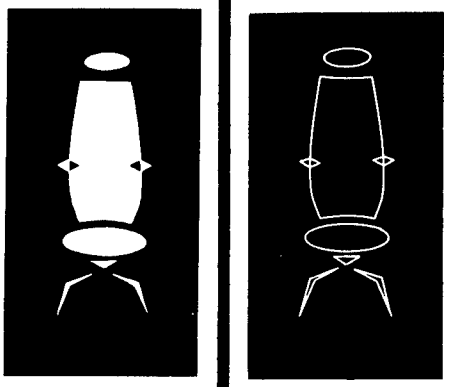


PART 3 APPENDICES

APPENDIX I

ANTHROPOMETRIC MEASUREMENTS OF SUBJECTS

TABLE 11

Anthropometric Measurements of Subjects*

Subject	Stature		Sitting Height (to top of Head)		Shoulder Height (Sitting Acro.)		Elbow Rest Height Sitting		Buttock - Leg Length		Buttock - Knee Length	
	In.	%	In.	%	In.	%	In.	%	In.	%	In.	%
1. R.H.W.	74.6	99	37.4	87	24.6	90	9.1	50	48.6	99	26.0	98
2. W.P.	74.4	98	37.6	90	25.2	95	9.2	53	47.6	99	25.4	95
3. J.W.	74.4	98	37.2	84	23.6	60	8.4	25	46.0	95	23.9	60
4. J.R.	74.3	98	36.6	70	22.9	38	8.0	13	48.3	99	26.0	98
5. W.B.	74.3	98	37.8	93	23.9	70	9.0	45	48.2	99	25.7	97
6. B.H.	73.0	94	37.4	87	24.2	80	9.2	53	45.3	90	24.9	89
7. E.G.	71.3	82	37.1	82	23.7	65	9.9	78	44.9	85	24.2	70
8. A.M.	69.8	61	36.9	77	23.5	58	8.9	40	43.3	62	23.4	40
9. R.A.W.	69.3	54	34.8	18	21.5	7	7.6	8	46.1	95	24.1	68
10. R.N.	68.8	44	35.6	40	21.9	11	8.5	28	45.4	92	23.3	38
11. W.S.	68.7	43	36.4	63	23.6	60	9.6	65	42.5	47	23.9	60
12. D.S.	68.4	38	35.3	30	22.8	35	8.5	28	43.1	58	23.9	60
13. R.S.	67.4	25	35.2	28	22.6	29	8.3	20	41.9	35	22.4	13
14. B.G.	67.2	22	35.4	33	23.2	48	9.3	55	42.7	50	23.1	30
15. A.L.M.	66.5	15	35.0	23	22.7	30	8.1	15	41.8	33	23.3	38
16. R.T.	65.8	9	33.2	2	20.7	2	7.0	2	42.5	47	23.2	35
17. D.H.	64.2	2	32.2	1	20.7	2	7.4	5	40.2	12	22.2	9
18. G.D.	64.2	2	35.0	23	22.0	12	7.0	2	40.0	8	21.4	2

(Table 11 continued on page 80.)

APPENDIX I (Continued)

TABLE 11 (Continued)

Subject	Knee Height (Sitting)		Shoulder Breadth (at deltoid)		Waist Circum.		Hip Breadth (Sitting)		Weight		Age	
	In.	%	In.	%	In.	%	In.	%	Lbs.	%	Yrs.	%
1. R.H.W.	24.6	99	18.5	75	39.2	98	15.4	95	205	97	21	3
2. W.P.	24.2	99	19.3	94	35.4	86	15.2	92	195	92	23	10-25
3. J.W.	23.2	93	18.9	88	29.6	23	13.4	25	155	38	23	25
4. J.R.	24.5	99	19.7	97	33.9	74	15.3	94	190	88	21	3
5. W.B.	23.6	98	17.8	48	32.4	59	14.8	83	185	84	20	1
6. B.H.	23.3	95	17.6	40	32.6	61	15.1	90	180	80	21	3
7. E.G.	22.7	85	17.6	40	32.2	57	13.4	25	175	73	23	10-25
8. A.M.	21.1	28	19.6	97	29.7	24	13.6	35	160	48	26	25-50
9. R.A.W.	22.0	63	18.2	65	34.6	80	14.6	75	165	55	18	1
10. R.N.	21.5	43	18.1	60	32.1	55	13.0	13	175	73	20	1
11. W.S.	20.9	23	19.1	90	33.0	66	14.1	58	157	41	33	90
12. D.S.	21.9	60	18.9	88	31.3	45	15.7	97	168	60	21	3
13. R.S.	21.3	35	17.6	40	30.9	40	14.7	80	156	40	28	50-75
14. B.G.	20.6	15	17.0	15	31.7	50	14.6	75	145	20	21	3
15. A.L.M.	21.1	28	18.1	60	36.1	89	15.4	95	180	80	21	3
16. R.T.	21.4	40	18.5	75	34.3	78	14.2	60	167	60	21	3
17. D.H.	20.7	18	16.1	2	29.8	25	13.1	15	135	8	18	1
18. G.D.	19.8	3	15.9	1	27.6	4	12.9	10	125	2	19	1

*The anthropometric measurements were made according to the procedures described in Hertzberg, Daniels, and Churchill, Anthropometry of Flying Personnel - 1950 (6). The percentile ratings indicated on this chart are not based upon the present subject series, but are the nearest interpolations to the percentiles of the Air Force population as revealed in the survey of 1950 (6).

APPENDIX II

QUESTIONNAIRES USED IN SEAT TESTING PROCEDURES

Bio-Mechanics Laboratory
Tufts University
Medford 55, Massachusetts

SEAT EVALUATION PROGRAM

GENERAL INFORMATION

Subject:_____ Date:_____

Age:_____ yrs. Exp. No.:_____

Weight_____ lbs. Seat No.:_____

Height_____ in. Seat Test No.:_____

Quest. Period:___to___

Clothing worn:_____ Experimenter:_____

Bio-Mechanics Laboratory
Tufts University
Medford 55, Massachusetts

SEAT EVALUATION PROGRAM
PRE-TEST QUESTIONNAIRE

The questions listed in this questionnaire are meant to provide information about your general states of health, comfort, fatigue, etc., before the seat test is given. Think carefully about each question before you answer it.

A. Personal History

1. Do you now feel discomfort because of any of the following conditions?

____a) Allergies
____b) Headaches
____c) Earaches
____d) Visual fatigue
____e) Sinus trouble
____f) Colds
____g) Dental trouble
____h) Intestinal trouble
____i) Respiratory trouble
____j) Dizziness
____k) Skin irritations
____l) Other

COMMENTS:

2. Indicate the number of hours of sleep you had during the last two nights.

____Hours last night.
____Hours the night before last.

COMMENTS:

B. Condition immediately prior to test.

1. How would you rate your state of hunger at this time?

____a) Uncomfortably full
____b) Full
____c) Just right
____d) Hungry
____e) Uncomfortably hungry

COMMENTS:

2. Do you feel any stiffness or soreness in the muscles of any of the following regions of the body:

____a) Neck
____b) Arms
____c) Back
____d) Chest
____e) Abdomen
____f) Legs
____g) Other

COMMENTS:

3. How would you describe the room temperature at this time?

____a) Too hot
____b) Warm
____c) Just right
____d) Cool
____e) Too cold

COMMENTS:

4. Is your clothing comfortable?

____Yes
____No

COMMENTS:

5. Does your clothing offer discomfort in any of the following regions of the body?

____a) Neck
____b) Wrists
____c) Under the arms
____d) Waist
____e) Crotch
____f) Buttocks
____g) Feet (shoes)
____h) Other

COMMENTS:

Bio-Mechanics Laboratory
Tufts University
Medford 55, Massachusetts

SEAT EVALUATION PROGRAM
TEST QUESTIONNAIRE

Subject:_____

Date:_____
Exp. No.:_____
Seat No.:_____
Seat Test No.:_____
Quest. No.:_____
Quest. Period:____ to_____
Experimenter:_____

Answer the following questions to the best of your ability. If the meaning of any question is not clear, do not hesitate to ask the experimenter to explain it. Because this is a general questionnaire, some of the questions may not apply to the particular seat which you are evaluating at this time. However, try to answer all of the questions which can be answered by a person who is sitting in this seat.

You will be given this same questionnaire from time to time throughout the experiment. This means that you will be answering these same questions periodically. Do not let your answers to the same questions on previous questionnaire presentations influence your judgment at any time, but try to answer the questions on the basis of how you feel at the moment. Sometimes you may find that your answers do not change. On other questions or at other times your impressions may change with continued experience in the seat. Remember that the important thing is how you feel at the moment; not how you may have felt before.

A. In the questions listed on this page, try to evaluate this seat in terms of the comfort that you anticipate it will provide.

---

1. What is your impression of the degree of comfort that this seat provides at the moment?

____a) It is the most comfortable seat I have ever sat in.
____b) It is extremely comfortable.
____c) It is moderately comfortable.
____d) It is mildly comfortable.
____e) It is neither comfortable nor uncomfortable.
____f) It is mildly uncomfortable.
____g) It is moderately uncomfortable.
____h) It is extremely uncomfortable.
____i) It is so uncomfortable that I cannot tolerate it.

2. At this moment, what is your estimate of the number of additional hours that you could sit in this seat before an intense desire to get out of it develops?

____Hours.

B. Evaluate this seat on the basis of how you feel now. This section deals with your state of comfort or discomfort at the moment. Do not evaluate the seat on the basis of past or future (anticipated) comfort.

1. Describe the degree of discomfort that you feel at this time in the following body regions.

	None	Slight	Moderate	Severe	Very Severe	Intolerable
a) Neck	____	____	____	____	____	____
b) Shoulders	____	____	____	____	____	____
c) Back	____	____	____	____	____	____
d) Buttocks	____	____	____	____	____	____
e) Thighs	____	____	____	____	____	____
f) Legs	____	____	____	____	____	____

2. Describe the sensations you feel in the following body regions. If none of the sensations listed apply to a particular region, leave a blank.

	Excessive Pressure	Stiffness	Ache	Soreness	Prickling Sensation	Numbness
a) Neck	____	____	____	____	____	____
b) Shoulders	____	____	____	____	____	____
c) Back	____	____	____	____	____	____
d) Buttocks	____	____	____	____	____	____
e) Thighs	____	____	____	____	____	____
f) Legs	____	____	____	____	____	____

3. Evaluate the following characteristics of this seat. Put a check mark next to the statement which applies.

I. Seat cushion:

a) The seat cushion is:

____ too firm
____ just right
____ too soft

b) The seat cushion is:

____ too wide
____ just right
____ too narrow

c) The seat cushion is:

____ too long
____ just right
____ too short

d) The seat cushion is responsible for excessive pressure exerted on:

____ the buttocks
____ the base of the spine
____ the thighs
____ no particular area

II. Seat back and cushion:

a) The back cushion is:

____ too firm
____ just right
____ too soft

b) The back cushion is:

____ too wide
____ just right
____ too narrow

c) The back cushion is:

____ too long
____ just right
____ too short

d) The back cushion gives poor support to:

____ the shoulders
____ the middle of the back
____ the small of the back
____ no particular area

III. Headrest. If there is a headrest, answer the following:

a) The headrest is:
____ too firm
____ just right
____ too soft

b) The headrest is:
____ too wide
____ just right
____ too narrow

c) The headrest is:
____ too high
____ just right
____ too low

d) The headrest is:
____ too far forward
____ just right
____ too far back

IV. Armrest. If there are armrests, answer the following:

a) The armrests are:
____ too long
____ just right
____ too short

b) The armrests are:
____ too wide
____ just right
____ too narrow

c) The armrests are:
____ too close together
____ just right
____ too far apart

d) The armrests are:
____ too high
____ just right
____ too low

C. Extrinsic discomfort. Evaluate your discomfort as it may be affected by the things listed below.

1. Do you feel any temperature discomfort?

____ Yes
____ No

2. Is this discomfort due to any of the following reasons?

____ The room temperature is too high.
____ The room temperature is too low.
____ My clothing is too heavy.
____ My clothing is too light.

3. Does your clothing restrict you in any of the following places?

____ Wrists
____ Under arms
____ Neck
____ Waist
____ Crotch
____ Buttocks
____ Feet (shoes)
____ Underwear (ill fitting)

4. Do you feel any discomfort due to the following conditions?

____ Headache
____ Sinus trouble
____ Cold
____ Earache
____ Hunger
____ Indigestion
____ Nausea
____ Perspiration
____ Other

Bio-Mechanics Laboratory
Tufts University
Medford 55, Massachusetts

SEAT EVALUATION PROGRAM
EXPERIMENTER'S QUESTIONNAIRE

These questions are to be asked by the experimenter whenever the subject makes an adjustment of his seat. Record the necessary data provided for in the space below.

Subject: _____

Date: _____
Exp. No.: _____
Seat No.: _____
Seat Test No.: _____
Time: _____
Experimenter: _____

A. Record the type of adjustment made.

Pan angle _____
Back angle _____
Vertical _____
Lateral _____
Swivel _____
Fore or Aft _____
Footrest fore or aft _____

B. Record the following information about the adjustment.

Pan angle: ____ degrees w/r horizontal.
Back angle: ____ degrees w/r vertical.
Included angle between back and pan: ____ degrees.
Vertical distance from SRP to floor: ____ inches.
Distance from SRP to footrest: ____ inches.
Swivel adjustment: Clockwise from neutral: ____ degrees.
Lateral distance to right (+) or left (-) of neutral: ____ inches.
Fore (+) or aft (-) distance from neutral: ____ inches.

Bio-Mechanics Laboratory
Tufts University
Medford 55, Massachusetts

SEAT EVALUATION PROGRAM
POST-TEST QUESTIONNAIRE

Subject: _____

Date: _____
Exp. No.: _____
Seat No.: _____
Seat Test No.: _____
Quest. Period: _____
Experimenter: _____

This part of the questionnaire is meant to provide information about your general evaluation of the seat and suggestions for improving the comfort and utility of the seat. Think carefully about the questions before answering them.

A. Evaluation of the comfort characteristics of the seat.

1. What, if any, changes could be made in this seat to make it more comfortable for use over long periods of time?

a) The seat cushion should be:

____softer.
____firmer.
____longer.
____shorter.
____wider.
____narrower

COMMENTS:

b) The shape of the seat should:

____be contoured on its surface to fit the buttocks.
____be contoured on its surface to fit the thighs.

COMMENTS:

c) The seat back cushion should be:

____softer.
____firmer.
____longer.
____shorter.
____wider.
____narrower.

COMMENTS:

d) The shape of the seat cushion should:

____ offer more support to the small of the back.
____ offer more support to the middle of the back.
____ offer more support to the shoulders.

COMMENTS:

e) If thigh pads are present, evaluate them in terms of the following:

____ They are good features of the seat and add to its comfort.
____ They would be good comfort features of the seat only if certain changes were made in them.
____ It does not make any difference whether they are present or not because they do not affect comfort.
____ They are poor features and the seat would be more comfortable without them.

COMMENTS:

f) If armrests are present, evaluate them in terms of the following:

They should be:

____ longer
____ shorter
____ wider
____ narrower
____ higher
____ lower
____ further apart
____ closer together

COMMENTS:

g) If a headrest is present, evaluate it in terms of the following:

It should be:

____ firmer
____ softer
____ lower
____ higher
____ wider
____ narrower
____ further forward
____ further back

COMMENTS:

h) The seat would be more comfortable if certain structural changes such as the following were made:

____ armrests added
____ headrest added
____ other

COMMENTS:

B. Evaluate the comfort characteristics of the seat in terms of the adjustment it provides:

1. ____ There are enough adjustments.
____ There should be more adjustments.
____ There should be more seat pan adjustments.
____ There should be more back adjustments.
____ There should be more height adjustments.
____ Other

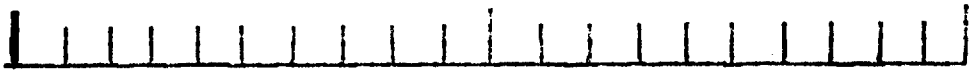
COMMENTS:

2. Evaluate the ease of manipulation of the seat adjustment controls.

	Just right	Adequate	Inaccessible	Hard to reach	Hard to move	Confusing	Inadequate
a) Seat angle	____	____	____	____	____	____	____
b) Back angle	____	____	____	____	____	____	____
c) Height	____	____	____	____	____	____	____
d) Fore and Aft	____	____	____	____	____	____	____
e) Lateral	____	____	____	____	____	____	____
f) Swivel	____	____	____	____	____	____	____

C. This part of the questionnaire gives you an opportunity to make any comments that you wish to make about the seat, the seat test, your comfort state, and to offer any suggestions that you like. Write freely and in as much detail as possible. You may continue your comments on the back of this page.

D. Place a check mark somewhere along the scale below to show how you would rate this seat in terms of the comfort it affords. Record your impressions, taking everything in general into account.



Intolerable Discomfort — Neutral — Ideal Comfort

APPENDIX III

SITTING TIME

TABLE 12

Latin Square Used for the Experiment*

Subjects	Session I	II	III	IV	V	VI
1. J.R.	1	4	X	2	6	5
2. R.H.W.	2	X	6	1	5	4
3. W.B.	X	6	1	5	4	2
4. J.W.	4	2	5	6	1	X
5. B.H.	5	1	4	X	2	6
6. W.P.	6	5	2	4	X	1
7. R.T.	1	4	X	2	6	5
8. G.D.	2	X	6	1	5	4
9. R.S.	X	6	1	5	4	2
10. A.L.M.	4	2	5	6	1	X
11. B.G.	5	1	4	X	2	6
12. W.S.	6	5	2	4	X	1
13. A.M.	1	4	X	2	6	5
14. D.H.	4	2	5	6	1	X
15. D.S.	5	1	4	X	2	6
16. E.G.	6	5	2	4	X	1
17. R.N.	1	4	X	2	6	5
18. R.A.W.	5	1	4	X	2	6

*Two of the seat sequences shown for subjects 13-18 are repeated. The Latin Square involved here could not be completed since two "extra" (i.e., beyond the 18 required) subjects had already started the experiment with other than the missing sequences.

Analysis of Sitting Time for Subjects 1 - 12

Table 13 summarizes an analysis of variance based upon a replicated Latin Square (sitting time scores for subjects 1 - 12 in Table 12). The partitioning of the total variance into its various components follows the procedure outlined by Edwards (3; pp. 319 ff.). Tables 14 and 15 are rearrangements of basic data for seats and sessions respectively.

The results of the analysis are self-evident but a few additional statements may be added for interpretation.

Neither variance due to sequence (line a) nor that for the Latin Square residual (line e) is significant. The sequence term has to do with the six unique serial arrangements of seats for testing purposes. The lack of significance ($F = 1.31$) indicates that there is no evidence to suggest that the use of one of the six seat sequences was more advantageous for testing than was any of the remaining sequences.

The Latin Square residual is based upon the pattern of experimental errors that remain as a unique contribution of the square itself. That the variance was not significant when tested against replication (viz., the residual within subjects, line f) simply means that either the interaction was not significant or that with replication it cancelled out.

Seats had a differential effect upon sitting time that was statistically significant (cf. line c; $F = 9.60$, $p < .01$). Mean differences were further tested by the Duncan Range Test (2). The test examines pairwise differences among treatment means in order to produce decisions on the relative merits of the treatments considered in all possible pairs. Procedure is as follows: The means are ranked and each one is taken in turn to determine whether it is "significantly" larger than each of the other means below it in size. On the basis of the comparisons, it can be determined whether certain of the treatments group together (i.e., are not statistically distinguishable) and how many significant groupings are established.

The ranked sitting times (average scores) for the six seats appear below.

Seat:	(#6)		(#2)	(#1)		(#4)	(#5)		(#X)
Minutes:	400.4		368.3	365.0		309.9	308.2		267.1
	Sub-Group A					Sub-Group B			

All pairs of means not appearing together within a bracket differ significantly from one another (e.g., Seat #X differs significantly from Seats #1, #2, and #6; Seat #5 differs from Seats #1, #2, and #6, etc.). Mean sitting times that appear for seats within a bracket cannot be statistically distinguished one from another. Two significantly different sub-groups have thus been established on the basis of pairwise comparisons of sitting time ($p < .05$). One sub-group (A) is characterized by long sitting periods and the second sub-group (B) is made up of seats that can be tolerated for a significantly shorter sitting period. Intra-group differences are not significant, however.

TABLE 13

Summary of Analysis of Variance for Sitting Time (n = 12).

Source of Variation	d.f.	Mean Square	F	p
Independent Observations:				
a. Sequence	5	10726.19	1.31	-
b. Residual between Subjects (error term)	6	8210.29		
Total Between Subjects:	11			
Correlated Observations:				
c. Seats	5	29488.26	9.60	.01*
d. Sessions	5	8090.86	2.63	.05
e. Residual from Latin Sq.	20	3764.09	1.22	
f. Residual within Subjects (error term)	30	3070.82		
Total Within Subjects:	60			
Total for Experiment:	71			

*The assumption of homogeneity of variance was tested for seats by means of Bartlett's test (3; p. 196). This assumption was rejected at the 5% level of confidence. While it is possible that a transformation of data could reduce heterogeneity, Norton (9; pp. 78-86) has pointed out that the effect of heterogeneity is not of great importance unless it exists in great magnitude. Because of this conclusion and because of the level of significance obtained for non-transformed data ($p < .001$), no transformations were attempted. The heterogeneity of variance found for seats is probably due to scores made on Seat #6. For this seat variance was low because a large number of subjects was able to sit up to the cut-off point of seven hours. To compensate for the possible effect of heterogeneity, the .01 level of confidence may be regarded as equivalent to the .001 level of confidence obtained above.

TABLE 14

Sitting Time in Minutes as a Function of Seats

Subjects	Seat #1	Seat #2	Seat #X	Seat #4	Seat #5	Seat #6
1. J.R.	420	420	286	215	240	360
2. R.H.W.	300	291	310	300	240	360
3. W.B.	420	420	420	360	420	420
4. J.W.	225	245	225	420	295	405
5. B.H.	420	400	203	420	390	405
6. W.P.	420	360	240	220	240	335
7. R.T.	406	295	231	209	250	420
8. G.D.	212	405	240	230	240	420
9. R.S.	383	383	285	205	283	420
10. A.L.M.	420	420	240	420	295	420
11. B.G.	420	420	240	300	420	420
12. W.S.	345	360	285	420	385	420
13. A.M.	*	400	157	283	215	385
14. D.H.	*	400	140	246	230	410
15. D.S.	420	300	300	*	*	420
16. E.G.	330	420	220	285	202	420
17. R.N.	289	400	325	*	420	420
18. R.A.W.	420	420	185	210	292	*
Mean (Ss. 1 - 12):	365.9	368.3	267.1	309.9	308.2	400.4
Standard deviation:	78.5	60.3	57.5	93.3	74.1	30.6
Mean (Ss. 1 - 18):	365.6	375.5	251.8	296.4	297.5	403.5
Standard Deviation:	73.4	55.3	65.8	85.0	78.0	26.9

*Missing score

TABLE 15

Sitting Time in Minutes as a Function of Session

Subjects	Session I	II	III	IV	V	VI
1. J.R.	420	215	286	420	360	240
2. R.H.W.	291	310	360	300	240	300
3. W.B.	420	420	420	420	360	420
4. J.W.	420	245	295	405	225	225
5. B.H.	390	420	420	203	400	405
6. W.P.	335	240	360	220	240	420
7. R.T.	406	209	231	295	420	250
8. G.D.	405	240	420	212	240	230
9. R.S.	285	420	383	283	205	383
10. A.L.M.	420	420	295	420	420	240
11. B.G.	420	420	300	240	420	420
12. W.S.	420	385	360	420	285	345
13. A.M.	*	283	157	400	385	215
14. D.H.	246	400	230	410	*	140
15. D.S.	*	420	*	300	300	420
16. E.G.	420	202	420	285	220	330
17. R.N.	289	*	325	400	420	420
18. R.A.W.	292	420	210	185	420	*
Mean (Ss. 1 - 12):	386	329	344	320	318	323
Standard Deviation:	51.8	93.0	62.1	91.1	82.8	83.6
Mean (Ss 1 - 18):	367	333	322	323	327	318
Standard Deviation:	64.8	91.8	81.4	86.1	85.2	93.4

*Missing Scores

APPENDIX IV

SEAT EVALUATION OF COMFORT SCALE

Table 16 shows the "rating-scores" assigned to a subject's placement of a check mark on a 20-interval rating continuum having specified anchor points as: "Intolerable Discomfort" (assigned a rating score of -10) and "Ideal Comfort" (assigned a rating score of +10). Some of the tabulated ratings (e.g., +7.6, -3.8, etc.) represent the experimenter's estimated values for check marks that fell between scale divisions. The ranks appearing with each score represent the relative order of seat preference for each subject.

The ranks shown for each rating were used to test the statistical significance of seat preferences. The Chi-Square Test outlined by Friedman (4) was used since it does not require the assumption of normality of the data which underlie such procedures as the analysis of variance. In addition, this test is adaptable to situations where the data are obtained originally in qualitative categories, but are not susceptible to exact measurement.

A Chi-Square statistic is found by the following formula:

$$\chi^2_r = \left[\frac{12}{np\,(p+1)}\right] \times \text{Sum (rank totals)}^2 - 3n\,(p+1)$$

where: p = number of treatments (seats)

n = number of replications (subjects)

12 and 3 are constants

For the ranked ratings in Table 16, $\chi^2_r = 63$ for 5 degrees of freedom. A χ^2_r value of only 21 is necessary at the .001 level of confidence.

APPENDIX IV

COMFORT SCALE EVALUATION

TABLE 16

Ratings Assigned to Comfort Scale Evaluations
(Ratings ranked for Subjects)

Subject	Seat #1		Seat #2		Seat #X		Seat #4		Seat #5		Seat #6	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1. J.R.	+ 7.6	1	+ 6.0	2	- 2.0	6	+ 1.6	4	- 1.5	5	+ 4.0	3
2. R.H.W.	+ 2.0	3.5	+ 3.0	2	- 4.0	6	- 3.4	5	+ 2.0	3.5	+ 6.0	1
3. W.B.	+ 3.0	3	+ 4.3	2	- 6.0	6	- 3.0	5	- 2.2	4	+ 8.0	1
4. J.W.	- 3.8	6	+ 4.0	2	- 1.0	4	+ 2.0	3	- 2.0	5	+ 6.0	1
5. B.H.	+ 8.0	1.5	+ 7.0	3	- 7.0	6	- 2.0	5	+ 4.0	4	+ 8.0	1.5
6. W.P.	+10.0	1	+ 6.0	2	- 9.8	6	- 7.0	4	- 8.0	5	+ 4.0	3
7. R.T.	+ 0.3	3	+ 4.5	2	- 7.6	6	- 4.6	4.5	- 4.6	4.5	+ 7.3	1
8. G.D.	- 6.0	5	+ 3.0	2	- 7.0	6	- 1.0	3	- 3.0	4	+ 6.0	1
9. R.S.	+ 4.0	2.5	+ 4.0	2.5	- 6.0	6	- 5.0	5	- 2.0	4	+ 8.0	1
10. A.L.M.	0.0	3	+ 5.0	1	- 5.2	6	0.0	3	- 0.2	5	0.0	3
11. B.G.	+ 5.0	2	+ 4.0	3	- 8.0	6	- 5.0	5	+ 2.0	4	+ 9.0	1
12. W.S.	+ 4.0	2.5	+ 4.0	2.5	- 5.0	6	- 1.0	4.5	- 1.0	4.5	+ 7.0	1
13. A.M.	+ 5.0	2.5	+ 5.0	2.5	- 5.0	6	0.0	5	- 4.0	4	+ 6.0	1
14. D.H.	0.0	5	+ 8.0	1.5	- 8.0	6	+ 4.0	3	+ 2.0	4	+ 8.0	1.5
15. D.S.*	+ 7.3	*	+ 7.5	*	- 3.6	*	0.0	*		*	+ 8.3	*
16. E.G.	+ 6.0	2.5	+ 6.0	2.5	- 0.0	5	+ 4.0	4	- 3.0	6	+ 8.0	1
17. R.N.	+ 1.5	5	+ 5.0	2	- 5.0	6	+ 4.5	3	+ 2.0	4	+ 7.0	1
18. R.A.W.	+ 5.0	3	+ 8.0	1.5	- 5.0	6	- 4.0	5	+ 3.0	4	+ 8.0	1.5
Average Score	+ 3.27		+ 5.24		- 5.29		- 1.11		- 0.97		+ 6.59	
Median Score	+ 4.0		+ 5.0		- 5.0		- 1.0		- 1.5		+ 7.0	

*Seats not ranked for this subject because of one missing score.

APPENDIX V

HOURLY EVALUATION OF DEGREE OF COMFORT SEAT PROVIDES

TABLE 17

Hourly Evaluation of Degree of Comfort Seat Provides

Questionnaire No.	Seat #1		Seat #2		Seat #X		Seat #4		Seat #5		Seat #6	
	No.* Ss.	Av.** Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score
1	16	+ 1.8	18	+ 2.0	18	+ 0.1	16	+ 0.7	17	+ 1.1	17	+ 2.5
2.	16	+ 1.6	18	+ 1.9	18	- 1.1	16	+ 0.1	17	+ 0.8	17	+ 2.3
3.	16	+ 1.8	18	+ 1.8	18	- 1.5	16	0.0	17	+ 0.2	17	+ 2.2
4.	16	+ 1.4	18	+ 1.4	18	- 2.0	16	- 0.1	17	- 0.2	17	+ 2.3
5.	16	+ 0.8	18	+ 1.3	15	- 2.3	16	- 0.4	17	- 0.9	17	+ 2.2
6.	14	+ 0.6	17	+ 0.8	7	+ 2.0	9	- 0.4	9	- 0.1	17	+ 2.1
7.	12	+ 0.5	14	+ 0.9	2	- 2.0	5	0.0	5	- 0.6	17	+ 1.9
8.	10	+ 1.0	12	+ 0.8	1	- 2.0	4	+ 0.3	5	- 0.8	14	+ 1.9
Total:												
Quest. 1-5:		+ 7.4		+ 8.4		- 6.8		+ 0.3		+ 1.0		+11.5
Quest. 1-8:		+ 9.5		+10.9		-12.8		+ 0.2		- 0.5		+17.4

*Number of subjects
**Average score

APPENDIX VI

HOURLY PREDICTION OF ADDITIONAL NUMBER OF HOURS SUBJECTS ESTIMATED THEY COULD SIT

TABLE 18

Hourly prediction of Additional Number of Hours Subjects Estimated They Could Sit

Questionnaire No.	Seat #1		Seat #2		Seat #X		Seat #4		Seat #5		Seat #6	
	No. Ss.	Av. Hours Pred.	No. Ss.	Av. Hours Pred.	No. Ss.	Av. Hours Pred.	No. Ss.	Av. Hours Pred.	No. Ss.	Av. Hours Pred.	No. Ss.	Av. Hours Pred.
1.	16	6.8	18	5.9	18	4.7	16	5.4	17	4.9	17	6.5
2.	16	6.3	18	5.3	18	3.6	16	4.4	17	4.8	17	6.3
3.	16	5.5	18	4.9	18	2.8	16	3.5	17	3.9	17	5.7
4.	16	4.6	18	3.8	18	1.8	16	2.8	17	3.0	17	5.1
5.	16	3.5	18	3.2	15	0.7	16	1.8	17	1.7	17	4.4
6.	14	3.1	17	2.4	7	0.4	9	1.9	9	1.4	17	2.9
7.	12	2.5	14	2.0	2	1.0	5	2.6	5	2.0	17	2.7
8.	10	2.8	12	1.4	1	1.0	4	1.8	5	1.4	14	2.2
Total:												
Quest. 1-5		23.2		19.9		12.9		16.1		16.6		23.6
Quest. 1-8		35.1		28.9		16.0		24.1		23.1		35.8

APPENDIX VII

HOURLY PROGRESSION OF SPECIFIC BODY DISCOMFORT

TABLE 19

Discomfort in the Neck

Questionnaire No.	Seat #1		Seat #2		Seat #X		Seat #4		Seat #5		Seat #6	
	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score
1.	16	0.0	18	0.1	18	0.1	16	0.0	17	0.1	17	0.0
2.	16	0.1	18	0.1	18	0.3	16	0.3	17	0.3	17	0.2
3.	16	0.1	18	0.2	18	0.3	16	0.3	17	0.5	17	0.2
4.	16	0.4	18	0.3	18	0.5	16	0.6	17	0.4	17	0.2
5.	16	0.6	18	0.3	15	0.5	16	0.6	17	0.7	17	0.2
6.	14	0.4	17	0.5	7	0.0	9	0.3	9	0.2	17	0.2
7.	12	0.5	14	0.6	2	0.0	5	0.0	5	0.4	17	0.3
8.	10	0.6	12	0.6	1	1.0	4	0.0	5	0.6	14	0.5
Total:												
Quest. 1-5		1.2		1.0		1.7		1.8		2.0		0.8
Quest. 1-8		2.7		2.7		2.7		2.1		3.2		1.8

APPENDIX VII (Continued)

TABLE 20

Discomfort in the Shoulders

Questionnaire No.	Seat #1		Seat #2		Seat #X		Seat #4		Seat #5		Seat #6	
	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score
1.	16	0.0	18	0.0	18	0.0	16	0.0	17	0.1	17	0.0
2.	16	0.0	18	0.0	18	0.2	16	0.2	17	0.1	17	0.0
3.	16	0.0	18	0.0	18	0.3	16	0.3	17	0.1	17	0.0
4.	16	0.1	18	0.1	18	0.3	16	0.4	17	0.5	17	0.0
5.	16	0.1	18	0.0	15	0.3	16	0.7	17	0.7	17	0.1
6.	14	0.3	17	0.0	7	0.1	9	0.4	9	0.1	17	0.3
7.	12	0.2	14	0.0	2	0.0	5	0.2	5	0.2	17	0.3
8.	10	0.1	12	0.1	1	0.0	4	0.3	5	0.2	14	0.2
Total:												
Quest. 1-5:		0.2		0.1		1.1		1.6		1.5		0.1
Quest. 1-8:		0.8		0.2		1.2		2.5		2.0		0.9

TABLE 21

Discomfort in the Back

Questionnaire No.	Seat #1		Seat #2		Seat #X		Seat #4		Seat #5		Seat #6	
	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score
1.	16	0.0	18	0.2	18	0.2	16	0.1	17	0.1	17	0.1
2.	16	0.1	18	0.2	18	1.0	16	0.3	17	0.3	17	0.2
3.	16	0.3	18	0.2	18	1.2	16	0.8	17	0.7	17	0.2
4	16	0.5	18	0.3	18	1.4	16	1.0	17	0.9	17	0.3
5.	16	0.7	18	0.9	15	1.9	16	1.2	17	1.6	17	0.4
6.	14	0.8	17	0.8	7	2.0	9	0.9	9	1.1	17	0.5
7.	12	1.1	14	1.1	2	1.0	5	0.8	5	0.8	17	0.8
8.	10	0.8	12	1.2	1	1.0	4	1.3	5	1.0	14	0.9
Total:												
Quest. 1-5		1.6		1.8		5.7		3.4		3.6		1.2
Quest. 1-8		3.3		4.9		9.7		6.4		6.5		3.4

APPENDIX VII (Continued)

TABLE 22

Discomfort in the Buttocks

Questionnaire No.	Seat #1		Seat #2		Seat #X		Seat #4		Seat #5		Seat #6	
	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score
1.	16	0.1	18	0.1	18	0.3	16	0.1	17	0.2	17	0.0
2.	16	0.2	18	0.3	18	1.6	16	0.5	17	0.7	17	0.1
3.	16	0.3	18	0.6	18	1.7	16	0.6	17	1.4	17	0.4
4.	16	0.8	18	1.1	18	1.9	16	1.1	17	1.8	17	0.4
5.	16	1.1	18	1.2	15	2.7	16	1.4	17	2.1	17	0.5
6.	14	1.2	17	1.3	7	2.6	9	1.7	9	2.2	17	0.8
7.	12	1.4	14	1.4	2	2.0	5	1.6	5	2.0	17	1.2
8.	10	1.1	12	1.5	1	2.0	4	1.5	5	2.0	14	1.2
		—		—		—		—		—		—
Total:												
Quest. 1-5:		2.5		3.3		8.2		3.7		6.2		1.4
Quest. 1-8:		6.2		7.5		14.8		8.5		12.4		4.6

APPENDIX VII (Continued)

TABLE 23

Discomfort in the Thighs

Questionnaire No.	Seat #1		Seat #2		Seat #X		Seat #4		Seat #5		Seat #6	
	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score
1.	16	0.0	18	0.0	18	0.0	16	0.5	17	0.0	17	0.0
2.	16	0.1	18	0.1	18	0.2	16	1.2	17	0.1	17	0.0
3.	16	0.1	18	0.1	18	0.3	16	1.3	17	0.1	17	0.0
4.	16	0.2	18	0.1	18	0.4	16	1.4	17	0.4	17	0.1
5.	16	0.2	18	0.0	15	0.3	16	1.8	17	0.8	17	0.0
6.	14	0.2	17	0.1	17	0.6	9	1.8	9	0.1	17	0.2
7.	12	0.7	14	0.1	2	0.5	5	0.8	5	0.6	17	0.3
8.	10	0.4	12	0.2	1	0.0	4	1.5	5	0.6	14	0.5
Total:												
Quest. 1-5		0.6		0.3		1.2		6.2		1.4		0.1
Quest. 1-8		1.9		0.7		2.3		10.3		2.7		1.1

APPENDIX VII (Continued)

TABLE 24

Discomfort in the Legs

Questionnaire No.	Seat #1		Seat #2		Seat #X		Seat #4		Seat #5		Seat #6	
	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score	No. Ss.	Av. Score
1.	16	0.1	18	0.0	18	0.0	16	0.1	17	0.0	17	0.0
2.	16	0.1	18	0.1	18	0.1	16	0.1	17	0.0	17	0.1
3.	16	0.1	18	0.1	18	0.1	16	0.3	17	0.1	17	0.0
4.	16	0.1	18	0.2	18	0.1	16	0.6	17	0.3	17	0.1
5.	16	0.2	18	0.2	15	0.1	16	0.6	17	0.6	17	0.1
6.	14	0.1	17	0.4	7	0.7	9	0.6	9	0.2	17	0.3
7.	12	0.2	14	0.3	2	1.5	5	0.4	5	0.2	17	0.4
8.	10	0.3	12	0.5	1	2.0	4	0.0	5	0.2	14	0.5
Total:												
Quest. 1-5:		0.6		0.6		0.4		1.7		1.0		0.3
Quest. 1-8:		1.2		1.8		4.6		2.7		1.6		1.5

TABLE 25

Total Average Hourly Discomfort in Each Body Region*

Questionnaire No.	Neck	Shoulders	Back	Buttocks	Thighs	Legs
1.	0.3	0.1	0.7	0.8	0.5	0.2
2.	1.3	0.5	2.1	3.4	1.7	0.5
3.	1.6	0.7	3.4	5.0	1.9	0.7
4.	2.4	1.4	4.4	7.1	2.6	1.4
5.	2.9	1.9	6.7	9.0	3.1	1.8
6.	1.6	1.2	6.1	9.8	3.0	2.3
7.	1.8	0.9	5.6	9.6	3.0	3.0
8.	3.3	0.9	6.2	9.3	3.2	3.5
Total:						
Quest. 1-5	8.5	4.6	17.3	25.3	9.8	4.6
Quest. 1-8	15.2	7.6	35.2	54.0	19.0	13.4

*Totals of average scores for each body region on all seats combined. See tables 19 - 24.

APPENDIX VII (Continued)

TABLE 26

Total Average Hourly Discomfort in Each Seat*

Questionnaire No.	Seat #1	Seat #2	Seat #X	Seat #4	Seat #5	Seat #6
1.	0.2	0.4	0.6	0.8	0.5	0.1
2.	0.6	0.8	3.4	2.6	1.5	0.6
3.	0.9	1.2	3.9	3.6	2.9	0.8
4.	2.1	2.1	4.6	5.1	4.3	1.1
5.	2.9	2.6	5.8	6.3	6.5	1.3
6.	3.0	3.1	6.0	5.7	3.9	2.3
7.	4.1	3.5	5.0	3.8	4.2	3.3
8.	3.3	4.1	6.0	4.6	4.6	3.8
Total:						
Quest. 1-5	6.7	7.1	18.3	18.4	15.7	3.9
Quest. 1-8	17.1	17.8	35.3	32.5	28.4	13.3

*Totals of average scores for each seat with all body regions combined. See tables 19 - 24.

APPENDIX VII (Continued)

TABLE 27

Average Time of Onset of Discomfort in Minutes*

Seat No.	Neck No. Ss.	Neck Av. Time	Shoulders No. Ss.	Shoulders Av. Time	Back No. Ss.	Back Av. Time	Buttocks No. Ss.	Buttocks Av. Time	Thighs No. Ss.	Thighs Av. Time	Legs No. Ss.	Legs Av. Time	Average
1	8/16	206.3	4/16	255.0	11/16	196.4	14/16	167.1	8/16	219.4	5/16	195.0	198.0
2	9/18	197.8	2/18	345.5	13/18	164.6	17/18	147.1	4/18	265.0	6/18	246.7	189.2
X	7/18	133.9	5/18	134.0	14/18	92.6	18/18	48.7	6/18	130.0	4/18	197.0	99.1
4	7/16	128.6	6/16	130.0	12/16	145.0	15/16	118.0	13/16	41.5	8/16	142.5	112.6
5	10/17	126.0	8/17	165.0	13/17	124.6	16/17	71.3	7/17	171.4	8/17	225.0	134.5
6	7/17	197.1	6/17	240.0	10/17	180.0	12/17	210.0	5/17	300.0	5/17	252.0	220.0
Average:		164.7		191.0		147.4		121.2		159.0		206.8	

*Calculated only for subjects who reported discomfort. Ratios indicate proportion of subject sample reporting discomfort.

APPENDIX VIII

PHILOSOPHY UNDERLYING USE OF RATING PROCEDURES

The transformation of qualitative information into scalar form requires some statements about its validity. In general, arguments against the use of scales expressive of subjective experience stem from recourse to principles derived from the logic of measurement. It is often held that such scaling tends to imply that qualitative experiences are capable of quantitative measurement. This leads to the danger of treating qualitative judgments as indicative of well defined degrees of experience. Then, for purposes of describing and treating separate statements made by a number of individuals, recourse is often made to the symbolic representation of judgments in the form of numbers assigned to them. The danger exists that these numbers will then be operated upon after the rules of algebra and that the results will subsequently be taken as constituting an accurate reflection of what would have happened in the qualitative realm were it possible to manipulate the judgments themselves.

Rationale for Treating Subjective Data in this Report:

Because these inherent dangers are recognized, it may be well to state the manner in which qualitative information has been treated in this paper.

Almost all of the items included in the questionnaire represent some "scalar" representation of judgments about the comfort characteristics of seats or the comfort states of body regions. In most of the items, ordering was explicitly set forth in the form of categories that ranged from one extreme of comfort to the other. The categories were titled "extremely uncomfortable," "mildly uncomfortable," "mildly comfortable," etc. For the unstructured rating scale, ordering was provided by the use of a continuum to be marked by the individual and definitive anchor points were supplied.

The ordering of categories and the provision of markings on a rating continuum permitted the transformation of judgments into an ordinal scale (17). Numbers could be assigned because their isomorphic relationship preserved the ordering. The numbers were used merely to identify rank order and, in this sense, did no violence to measurement theory.

With the ordinal scale certain operations are permissible. Median ranks can be found and simple rank-order correlations can be used. In a strict sense, averages and standard deviations ought not to be used for they imply more information than is contained in the data (e.g., knowledge concerning the underlying parent distribution of ranks.) At the same time their use has pragmatic sanction if usage is not abused. For the present study, the use of average ranks was predicated on their utility for purposes of describing trends. In addition, averaging of ranks permitted later summation of these averages into indices specified as "Totals of Average Discomfort Scores." Something would have been lost in interpretation had a generalized median score been used for an index of over-all comfort.

In summary, a cautionary note may be appended. Wherever average ranks were used in the treatment of results they should be viewed purely as descriptive measures. No attempts were made, nor should be made, to imply degree of a comfort quality. For this specialized application the reader should return to the evaluative statements themselves, or to median scores. However, interpretation at this point should be judiciously applied since little or nothing is known about the intervals between ratings or comfort categories. An example will suffice to make this clear: Individuals may not be able to discriminate equally well between successive categories. Thus, they may not feel that the interval between "Extreme Discomfort" and "Mild Discomfort" represents the same degree of difference in experience as the interval between "Mild Discomfort" and "Slight Discomfort." Furthermore, an "average comfort rating" of 1.0 is not necessarily twice as large as one of 0.5, in the context of the present experiment. Whether these present difficulties can eventually be resolved must await the results of future experimentation.